PROTA

Dyes and tannins

Plant Resources of Tropical Africa 3

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- Prosea Foundation (PROSEA), P.O. Box 332, Bogor 16122, Indonesia

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Plant Resources of Tropical Africa 3

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Editors:	P.C.M. Jansen D. Cardon
General editors:	R.H.M.J. Lemmens L.P.A. Oyen

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Contributors

- C. Andary, Laboratoire de Botanique, Phytochimie et Mycologie, UMR 5175 (CEFE, CNRS), Faculté de Pharmacie, 15 Avenue Charles Flahault, 34093 Montpellier, France (*Anogeissus leiocarpa*)
- Getachew Aweke, P.O. Box 4278, Addis Ababa, Ethiopia (*Lawsonia inermis*)
- T.V. Balole, Botswana College of Agriculture, Private Bag 0027, Gaborone, Botswana (*Sorghum bicolor*)
- S.O. Bandeira, Department of Biological Sciences, Universidade Eduardo Mondlane, P.O. Box 257, Maputo, Mozambique (*Ceriops tagal*)
- D. Cardon, CNRS, CIHAM-UMR 5648, 18 Quai Claude Bernard, 69365 Lyon Cedex 07, France (*Baphia nitida, Indigofera arrecta, Indigofera tinctoria, Morinda lucida, Philenoptera cyanescens, Philenoptera laxiflora*, editor)
- B. Doumbia, Hamdallaye 507, Ségou, Mali (*Anogeissus leiocarpa*)
- R.W. Dunlop, Institute for Commercial Forestry Research, P.O. Box 100281, Scottsville 3209, South Africa (*Acacia mearnsii*)
- C.W. Fagg, Departamento de Engenharia Florestal, Faculdade de Tecnologia, Campus Universitario, Universidade de Brasilia, 71910 Brasilia DF, Brasil (*Acacia nilotica*)
- M. Garcia, Association 'Couleur Garance', Le Chateau, 84360 Lauris, France (*Anogeissus leiocarpa*)
- A. Gurib-Fakim, Chemistry Department, University of Mauritius, Reduit, Mauritius (*Haematoxylum campechianum*)
- P.C.M. Jansen, PROTA Network Office Europe, Wageningen University, P.O. Box 341, 6700 AH Wageningen, Netherlands (*Acridocarpus excelsus, Adenorandia kalbreyeri, Alectra sessiliflora, Aloe zebrina, Arnebia hispidissima, Baphia nitida, Bertiera spicata, Bixa orellana, Buchnera hispida, Caesalpinia coriaria, Caesalpinia sappan, Cochlospermum tinctorium, Combretum glutinosum, Cosmos sulphureus, Craterispermum laurinum, Craterispermum schweinfurthii, Cremaspora triflora, Crocus sativus, Cryptolepis sanguinolenta, Curcuma longa, Danais ligustrifolia, Diospyros loureiriana, Elephantorrhiza elephantina, Ficus glumosa, Flemingia grahamiana, Griffonia physocarpa, Impatiens tinctoria, Indigofera coerulea, Indigofera longiracemosa, Labourdonnaisia madagascariensis, Laguncularia racemosa, Lannea barteri, Lannea microcarpa, Lannea velutina, Ludwigia leptocarpa, Mucuna flagellipes, Mucuna poggei, Mucuna sloanei, Pauridiantha rubens, Philenoptera cyanescens, Philenoptera laxiflora, Phyllanthus bojerianus, Phyllanthus emblica, Psilanthus ebractiolatus, Psychotria psychotrioides, Pterocarpus soyauxii, Pterolobium stellatum, Pyranthus tullearensis, Rhus tomentosa, Rothmannia longiflora, Rothmannia whitfieldii, Senna auriculata, Striga gesnerioides, Syzygium rowlandii, Terminalia chebula, Terminalia scutifera, Xylocarpus granatum*, editor)
- R.N. Kaume, P.O. Box 583–90200, Kitui, Kenya (*Barringtonia racemosa*)
- G.M. Legwaila, Botswana College of Agriculture, Private Bag 0027, Gaborone, Botswana (*Sorghum bicolor*)

- R.H.M.J. Lemmens, PROTA Network Office Europe, Wageningen University, P.O. Box 341, 6700 AH Wageningen, Netherlands (*Indigofera arrecta*, general editor)
- V.N. Mainga, World Agroforestry Centre (ICRAF), P.O. Box 30677, Nairobi, Kenya (*Bruguiera gymnorhiza*)
- M. Marquet, CIHAM-UMR 5648, Université Lumière - Lyon 2, 18 Quai Claude Bernard, 69365 Lyon Cedex 07, France (*Combretum glutinosum*, *Lannea microcarpa*)
- B.K. Maundu, c/o Juma Simitu, World Agroforestry Centre (ICRAF), P.O. Box 30677, Nairobi, Kenya (*Ceriops tagal*)
- James Z.A. Mugedo, Department of Chemistry, Maseno University, Private Bag, Maseno, Kenya (*Acacia nilotica*)
- P.M. Njuguna, P.O. Box 1995, Thika, Kenya (*Euclea divinorum*)
- Achmad Satiri Nurhaman, Southeast Asian Regional Centre for Tropical Biology (SEAMEO BIOTROP), P.O. Box 17, Bogor, Indonesia (illustrations)
- M. Olivier, Sama Bioconsult, 27 Rue des neuf Soleils, 63000 Clermont-Ferrand, France (*Anogeissus leiocarpa*)
- L.P.A. Oyen, PROTA Network Office Europe, Wageningen University, P.O. Box 341, 6700 AH Wageningen, Netherlands (general editor)
- N. Sauvan, Laboratoire LVMH, Parfums et Cosmétiques, 45804 Saint Jean de Braye, France (*Anogeissus leiocarpa*)
- M.P. Setshogo, University of Botswana Herbarium, Department of Biological Sciences, University of Botswana, Private Bag UB00704, Gaborone, Botswana (*Tagetes erecta*)
- Iskak Syamsudin, Herbarium Bogoriense, Research Centre for Biology – LIPI, Jalan Ir. H. Juanda 22, Bogor 16122, Indonesia (illustrations)
- R. Takawira-Nyenya, National Herbarium and Botanical Garden, P.O. Box A 889, Avondale, Harare, Zimbabwe (*Indigofera tinctoria*, *Pterocarpus angolensis*)
- Suzanne Tapapul Lekoyiet, c/o Wolfgang Heutzen, District Agriculture Office, P.O. Box 19, Kilifti, Kenya (*Lawsonia inermis*)
- C. Zimudzi, University of Zimbabwe, Biological Sciences Department, P.O. Box MP 167, Mount Pleasant, Harare, Zimbabwe (*Morinda lucida*, *Rubia cordifolia*)

Acknowledgments

- I. Brémaud, 'Wood and Tree Mechanics' Team, Laboratory of Mechanics and Civil Engineering (LMGC), CNRS-UMR 5508, University of Montpellier 2, Place Eugène Bataillon, 34095 Montpellier Cedex 5, France (*Pterocarpus soyauxii)*
- A.-M. Etheve, Terre La Sarl, B.P. 117, 401 Mahajanga, Madagascar (dyes of Madagascar)
- G. Michaloud, Tropical forest ecology, Plant-insect relationships, UMR AMAP: botAnique et bioinforMatique de l'Architecture des Plantes, CNRS-CIRAD-INRA-Univ. Montpellier 2, IRAD, TA 40/PS2, Boulevard de la Lironde, 34398 Montpellier Cedex 5, France (*Ficus glumosa*)
- S. van Otterloo-Butler, Bowlespark 21, 6701 DR Wageningen, Netherlands (English language correction)
- N. Wulijarni-Soetjipto, PROSEA Network Office, P.O. Box 332, Bogor 16122, Indonesia (coordination illustrators)

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T.H.I.A.S. Tan, Databank Manager

Introduction

Choice of species

PROTA 3: 'Dyes and tannins' describes the cultivated and wild plant species of tropical Africa traditionally used for dyeing or tanning. Some of these are only used as a dye or a tannin, but most have several uses. PROTA normally assigns one primary use and if relevant, one or more secondary uses to all plant species used in Africa. PROTA 3: 'Dyes and tannins' comprises accounts of species whose primary use is dye or tannin. The primary use of *Acacia nilotica* (L.) Willd. ex Delile is as a tannin and dye, and thus it is treated in PROTA 3, but it has several secondary uses, e.g. the trees are widely planted as a fence, for shade and as ornamental, the trunk and branches yield a valuable gum, the wood is used for timber and fuel, the leaves and fruits are sources of fodder, the seeds are eaten, the bark is used for fibre, and from most plant parts traditional medicines are prepared. Also tamarind (*Tamarindus indica* L.) is quite important as a dye and tannin, but its primary use is undoubtedly its edible fleshy sweet-sour fruit, and consequently tamarind is described in PROTA 6: 'Fruits'.

Species that are used as a dye or tannin but have another primary use are listed after the primary use dyes and tannins, and are fully described in other commodity groups. Some important species included in this list are: garden beet (*Beta vulgaris* L.), capsicum pepper (*Capsicum annuum* L.) and safflower (*Carthamus tinctorius* L.).

In PROTA 3, three species are treated which, in addition to their primary use as dye or tannin, also have another primary use and consequently will be described in 2 commodity groups. These species are *Pterocarpus angolensis* DC. (also in PROTA 7: 'Timbers'), *Pterocarpus soyauxii* Taub. (also in PROTA 7: 'Timbers') and *Sorghum bicolor* (L.) Moench (also in PROTA 1: 'Cereals and pulses').

Dyes and tannins are closely related. The basic components of many vegetable dyes are chemically comparable to those of tannins and for this reason dye- and tannin-producing plants have been dealt with together in this volume. Some species are only used as a dye or as a tannin, but particularly the tannin producing species are often also used as a dye.

In PROTA 3: 'Dyes and tannins' comprehensive descriptions are given of 30 important dye and tannin species. These major dyes and tannins comprise most wild species, but also several cultivated or partly domesticated species. The accounts are presented in a detailed format and illustrated with a line drawing and a distribution map. In addition, accounts of 43 dyes and tannins of minor importance are given. Because information on these species is often scanty, these accounts are in a simplified format and do not include a drawing or map. For another 43 species the dye and tannin information was too scarce to justify an individual treatment and they have only been mentioned in the accounts of related species.

Theoretically numerous plant species can be used as a dye because most contain substances which can colour fibres, food or skin. Many plant species also contain tannins. For PROTA 3, however, only species have been chosen for which proof was found in the literature on African useful plants that they actually are or have been used as a dye or tannin. Such literature, however, is scarce, often old and usually poor in details about the use. Only species for which at least a practical application is known have been considered for treatment. This means that species mentioned in the literature but only with remarks such as 'the plant contains tannin' or 'the plant yields a black dye' have not been included.

The appearance of synthetic dyes and tannins in the second half of the 19th century eventually caused an almost complete disappearance of the natural ones in commercial dyeing and tanning and in scientific attention. In tropical Africa small-scale dyeing and tanning with materials of plant origin persisted only very locally and often escapes attention in ethnobotanical reports. Therefore, PROTA 3 does not claim to be comprehensive and particularly the dyes and tannins of Madagascar, which are poorly known, may be underrepresented.

At present the interest in natural dyes and tannins is increasing worldwide, mainly because they are less polluting and less or non-toxic. Natural food colorants are becoming particularly commercially important. In PROTA 3, however, little attention has been paid to food colorants because of the insignificance of their use in Africa. Not treated are, for example, red headed cabbage (*Brassica oleracea* L.), tea (*Camellia sinensis* (L.) Kuntze), many *Citrus* species, oil palm (*Elaeis guineensis* Jacq.), tomato (*Lycopersicon esculentum* Mill.) and cacao (*Theobroma cacao* L.). These species feature prominently in other commodity groups.

Plant names

Family: Apart from the classic family name, the family name in accordance with the Angiosperm Phylogeny Group (APG) classification is also given where it differs from the classic name.

Synonyms: Only the most commonly used synonyms and those that may cause confusion are mentioned.

Vernacular names: Only names in official languages of regional importance in Africa are included: English, French, Portuguese and Swahili. It is beyond the scope of PROTA to give an extensive account of the names of a species in all languages spoken in its area of distribution. Checking names would require extensive fieldwork by specialists. Although regional forms of Arabic are spoken in several countries in Africa, the number of African plant species that have a name in written, classical Arabic is limited. Arabic names are therefore omitted. Names of plant products are mentioned under the heading 'Uses'.

Origin and geographic distribution

To avoid long lists of countries in the text, a distribution map is added for major species. The map indicates in which countries a species has been recorded, either wild or planted. It should be realized that for many species these maps are incomplete because they are prepared on the basis of published information, the quantity and quality of which varies greatly from species to species. This is especially the case for wild species which are not or incompletely covered by the regional African floras, and for cultivated species which are only planted on a small scale (e.g. in home gardens). For some countries (e.g. Central African Republic, Chad, Sudan, Angola) there is comparatively little information in the literature. Sometimes they are not covered by recent regional or national floras and although species may be present there, this cannot be demonstrated or confirmed. For some major species, a distribution map has been omitted because there is too little information on distribution.

Properties

Although often poorly known, the chemistry of the colouring or tanning agents is given. In addition, compounds with possible or proven nutritional or medicinal value, toxins and other relevant chemical compounds are mentioned.

Description

A morphological characterization of the species is given. The description is in 'telegram' style and uses botanical terms. Providing a description for the general public is difficult as more generally understood terms often lack the accuracy required in a botanical description. A line drawing is added for all major and some lesser-known species to complement and visualize the description.

Management

Descriptions of husbandry methods including fertilizer application, irrigation, and pest and disease control measures are given under 'Management' and under 'Diseases and pests'. These reflect actual practices or generalized recommendations, opting for a broad overview but without detailed recommendations adapted to the widely varying local conditions encountered by farmers. Recommendations on chemical control of pests and diseases are merely indicative and local regulations should be given precedence. PROTA will participate in the preparation of derived materials for extension and education, for which the texts in this volume provide a basis, but to which specific local information will be added.

Genetic resources

The genetic diversity of many plant species in Africa is being eroded, sometimes at an alarming rate, as a consequence of habitat destruction and overexploitation. The replacement of landraces of cultivated species by modern cultivars marketed by seed companies is another cause of genetic erosion. Reviews are given of possible threats for plant species and of the diversity within species. Information on ex-situ germplasm collections is mostly extracted from publications of the International Plant Genetic Resources Institute.

References

The main objective of the list of references given is to guide readers to additional information; it is not intended to be complete or exhaustive. Authors and editors have selected major and other references; major references are limited to 10 references (5 for minor species), the number of other references is limited to 20 (10 for minor species). The references listed include those used in writing the account. Where data available on the internet have been used, the website and date are also cited.

Alphabetical treatment of dyes and tannins

ACACIA MEARNSII De Wild.

Protologue Pl. bequaert. 3(1): 61 (1925).

Family Mimosaceae (Leguminosae - Mimosoideae)

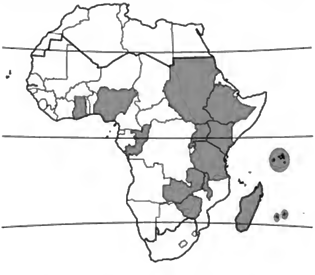
Chromosome number 2*n* = 26

Synonyms *Racosperma mearnsii* (De Wild.) Pedley (1986), *Acacia decurrens* auct. non Willd., *Acacia mollissima* auct. non Willd.

Vernacular names Black wattle, tan wattle (En). Acacia noir (Fr). Acácia negra (Po). Muwati (Sw).

Origin and geographic distribution Black wattle is native to south-eastern Australia from 35–44°S latitude (New South Wales, Queensland, Victoria and Tasmania). It has been introduced throughout the tropics and subtropics. Large commercial plantations are found in southern and eastern Africa (Kenya, South Africa and Zimbabwe), Brazil and India. Elsewhere plantings are smaller or introductions have not been successful.

Uses Black wattle is primarily cultivated for tannin and wood production. It is the world's principal source of tanbark; the bark contains up to 40% of excellent tannin especially suitable for use in the manufacture of heavy leather goods. In addition, the powdered bark extract is used to prepare tannin formaldehyde adhesives for exterior grade plywood, particle board and laminated timber. Possibilities of using the bark in the production of biodegradable polyurethane foam are being tested. The wood of the tree is widely used as fuelwood for domestic use and village industries, or for charcoal production (e.g. in Kenya, South Africa and Brazil). The wood may also be used for local construction material, mine props, wooden tools, joinery, flooring and hardboard. Thin, pliable stems are used in the framework of traditional wattle and daub huts by many African people. The wood is used in combination with other woods to produce paper pulp and dissolving (or viscose) pulp, the raw material used to produce synthetic fibres such as rayon. In recent years the use of black wattle wood in the pulp and paper industry has increased substantially worldwide. Japan in particular is a large importer of black wattle chips from South Africa. Black wattle is also planted for erosion control and soil improvement, as shelter belts or fire belts, as a shade tree in plantations, and as an ornamental. The leaves are sometimes used for fodder, but are relatively unpalatable and can best be mixed with other feeds. A decoction of the very astringent bark is used as a styptic and to treat diarrhoea.



Acacia mearnsii – planted and naturalized

Production and international trade The maximum area of black wattle plantations was reached around the 1960s. Since then, a fall in demand for vegetable tannin has led to a considerable reduction in area, e.g. from 325,000 ha to 130,000 ha in South Africa and from 27,000 ha to 14,000 ha in Zimbabwe. Around 1980 the estimated plantation area was about 350,000 ha, of which 160,000 ha were in South Africa, 125,000 ha in Brazil, 30,000 ha in East Africa (Zimbabwe, Kenya, Tanzania, Rwanda, Burundi), 20,000 ha in India, and 15,000 ha in Indonesia. Black wattle is currently the world's major source of vegetable tannin. In several countries, including Kenya, Zimbabwe and South Africa, tannin industries based on black wattle have been developed. South Africa also produces a variety of adhesives from the bark extracts. The main exporting countries are South Africa (30,000 t/year of tan extract and 15,000 t/year of adhesive products) and Kenya (25,000 t/year of tan extract, but the Kenyan factory has recently closed). These products are exported to many countries where niches are available for vegetable tannin extract and naturally derived adhesives.

For every 1 t of bark harvested from the trees about 5 t of timber is available. The timber is mainly traded locally. Some of the wood is converted to charcoal, part of which is exported, especially to Europe, but no production or export data are available. South Africa uses 160,000–200,000 t/year of air-dried wood in the production of dissolving pulp and exports about 1.1 million t/year of air-dried chips for pulp and paper production to Japan.

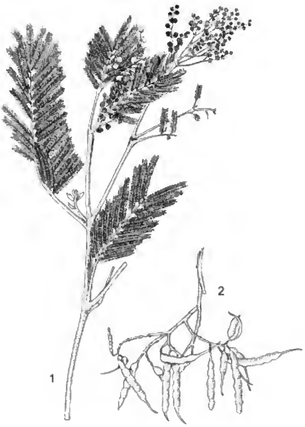
Properties The bark of black wattle contains 30–40% high-quality tannin on dry weight basis. The tannin belongs to the group of condensed proanthocyanidins, and is a complex mixture of some 40 components, mostly polymers of (+)-catechin, (–)-robinetinidin and (+)-gallocatechin. The tannin quickly penetrates the hide, and gives a firm and durable light-coloured leather, unlike other proanthocyanidin tanning materials (e.g. mangrove extracts) which give a reddish colour. It does not precipitate in acid solution, resulting in better quality leather. It is especially suited for the manufacture of sole leather for shoes.

The tannin content varies with bark thickness, age of the tree and average annual rainfall, and decreases from the base of the trunk upwards, the bark of the branches having a low tannin content. Black wattle extract contains 60–65% tannin. Extracts, usually called 'mimosa extract', are commercially available in several forms, each giving different qualities to leather. Usually the plant extract is mixed with synthetic tannins for use in the leather industry.

The wood is yellowish to pale red. Wood density ranges from 550–850 kg/m^3, depending on site conditions. The wood is moderately hard to hard, durable, and fairly tough and strong. It has an energy value of about 19,700 kJ/kg and ash content of about 1.5%. The energy value of charcoal is about 32,000 kJ/kg. The density and pulp yield of black wattle make it a very attractive alternative to *Eucalyptus globulus* Labill.

Adulterations and substitutes Other tanning agents, such as chromium salts and synthetic tannins (syntans, resin tannages and aldehyde tannages), are nowadays mostly used for tanning leather. Although some are highly toxic and polluting, they are considered as having a more specific activity and being more predictable and controllable in the tanning process. Sometimes chrome tanning or tanning with synthetic tannins is combined with vegetable tanning, e.g. re-tannage of chrome-tanned leather to develop special characteristics, or the use of chrome tannins for shoe upper leather and vegetable tannins for the sole.

Description Small to medium-sized evergreen tree up to 30 m tall; trunk straight, up to 50 cm in diameter; bark brownish-black, fissured, but in younger stems grey-brown and smooth; crown spreading, rounded at maturity; twigs unarmed, angled, grey, densely hairy when young. Leaves alternate, bipinnately compound, 8–15 cm long, with 8–20 pairs of pinnae 2–5 cm long; rachis with glands at base of each pair of pinnae on upper surface; leaflets very numerous, 20–70 pairs crowded on each pinna, narrowly oblong and small, 1.5–4 mm × 0.5–0.8 mm, blunt, with dense soft hairs, dark olive green. Inflorescence a globose head 5–8 mm in diameter, arranged in axillary racemes or panicles, head up to 50-flowered. Flowers bisexual, 5-merous, pale creamy-yellow, very sweet-scented; calyx lobes c. 1 mm long; corolla lobes c. 2 mm long, pointed at the apices; stamens 30–45, filaments up to 2.5 mm long; ovary superior, 1-celled, style long and slender. Fruit a narrowly oblong or linear, flat pod, (3–)5–10(–15) cm × 0.5–1 cm, constricted between the seeds, pubescent, dark brown to blackish when ripe, dehiscent along one suture, 3–14-seeded. Seeds ovoid, 3–5 mm × 2–3.5 mm, smooth and black, with a small yellowish-white aril.



Acacia mearnsii – 1, flowering branch; 2, branchlet with fruits.
Source: PROSEA

Other botanical information There has been considerable confusion about *Acacia mearnsii* and some closely allied species: *Acacia decurrens* Willd. (green wattle) and *Acacia dealbata* Link (silver wattle). These species have long been considered as conspecific with *Acacia mearnsii*, although usually distinguished as varieties. They are now usually thought to represent distinct species. The name *Acacia mollissima* has often been used erroneously for *Acacia mearnsii*. In fact, *Acacia mollissima* Willd. is a synonym for *Acacia pubescens* (Vent.) W.T.Aiton. The name *Acacia decurrens* is still commonly used for *Acacia mearnsii*, which makes literature on these species very confusing. *Acacia mearnsii* can be crossed with *Acacia decurrens*, *Acacia dealbata*, *Acacia baileyana* F.Muell. and *Acacia irrorata* Sieber ex Spreng. Hybrids have no real advantages over the parent species and are often partly sterile.

Anatomy Wood-anatomical description:

- Macroscopic characters:
  Heartwood pale brown with reddish markings, indistinctly demarcated from the pale straw-coloured sapwood. Grain often interlocked. Texture moderately fine.
- Microscopic characters:
  Growth rings indistinct. Vessels diffuse, 6–8/mm², in oblique or radial multiples of up to 4. Fibres 700–880 µm long and 9–21 µm in diameter. Parenchyma absent or scarce, vasicentric and aliform. Rays inconspicuous and narrower than vessels.

Growth and development Seeds stay viable for many years, both in storage and in the ground. Seeds in the ground start to germinate after a forest fire or land cultivation. Seedlings are susceptible to fire. On germination, the radicle grows downwards to form a taproot of about 1 m. Fast-growing lateral roots develop from the taproot just below the soil surface. Nodules formed by N-fixing bacteria usually appear on the lateral roots.

Black wattle is a light-demanding species with rapid early stem growth, reaching up to 3 m/year. Some trees start to flower when only about 2 years old. If the growing point is not damaged black wattle produces a fairly straight stem, sometimes almost circular but usually more or less elliptical in cross-section. Plantation grown trees have an average taper of 2.5 cm in 3 m, single trees show more taper. In commercial plantations in South Africa, trees at a rotation of 10 years are rarely shorter than 10 m and on good sites attain 27–30 m, with diameters at breast height seldom exceeding 30 cm. Crown shape in plantation trees usually assumes an inverted pear-shape with age, and is generally globose at maturity. Branches die progressively from below, due to shading and competition, and at maturity the crown occupies about one fifth of the stem length. The coppicing ability of black wattle is generally poor. The flowers are predominantly insect (bee) pollinated. Copious fruiting normally occurs after 5–6 years; fruits mature in 12–14 months. The lifespan is generally 15–20 years, but some seed orchards in South Africa are nearly 30 years old and still producing seed.

In some areas, such as Hawaii and parts of South Africa, black wattle has become a noxious weed due to its aggressive colonization of denuded areas and riparian zones.

Ecology In its natural area of distribution, black wattle occurs in the understorey of tall open forests, in fringes of closed forests or in dense thickets on recolonized lands. Its range is from sea-level to 900 m altitude, but it mainly occurs from sea-level to about 200 m in areas with a warm subhumid to humid climate. The mean maximum temperature of the hottest month is 21–28°C, the mean minimum of the coolest month 1–7°C, with up to 40 frost days. Annual rainfall varies from (450–)625–1000(–1600) mm. Black wattle is sensitive to severe drought and to frosts of –4°C or lower. It is also very sensitive to snow damage, either snapping or bending.

In tropical countries plantations occur under wetter conditions than in the natural area of distribution. These plantations are found in highlands (1500–2500 m) with a mean annual temperature of 12–20°C, mean minimum temperature of the coolest month 2–8°C, mean maximum temperature of the hottest month 18–24°C and mean annual precipitation of 700–2000 mm. In South Africa black wattle is cultivated at 300–1000 m altitude where the climate is intermediate between that of the tree's native range and tropical conditions.

Black wattle tolerates a variety of soils, but grows best in moist, well-drained, relatively deep and light-textured soils with pH 5–6.5. It does not grow on poorly-drained, calcareous or very infertile sites.

Propagation and planting Black wattle is usually propagated by seed, either sown directly in the field, or in a nursery. Seed weight is low; 1 kg contains 50,000–80,000 seeds. Germination is rapid if seeds have been pretreated with very hot water (90°C). Sometimes mechanical scarification is used. Seeds retain their viability for several (to over 50) years. Vegetative propagation is not very successful but rooted cuttings, bud grafts and tissue culture have been successful in South Africa. Normally no inoculation with *Rhizobium* is needed.

Standard cultural practices can be used to raise seedlings in the nursery. Plantation sites should be well prepared by ploughing or soil ripping for establishment, but for re-establishment pitting is sufficient land preparation.

When seedlings are used in Zimbabwe, the initial stocking is about 2500 stems/ha, or a spacing of 2.7 m × 1.5 m. This is reduced to 2000 stems/ha when trees are 4 m tall and to 1500–1700 stems/ha when they reach 7 m. Naturally regenerated stands are initially thinned into lines and then thinned to the same spacing as planted stands. When seedlings are used in South Africa, the initial stocking is about 2200 stems/ha, which is reduced to 1600 stems/ha in one or two thinning operations. The direct seeding method uses 3–5 kg/ha of seed, sown in drill lines. The large numbers of plants that grow are then rigorously thinned and initial management is more intense.

Normally black wattle is not mixed with other species because its rapid growth hinders their development.

Management During the first year plantations should be weeded. To maintain vigorous growth, thinning should start as early as 14 months after planting, and should be repeated at least once. The degree of thinning depends on the management objectives; severe thinning favours stem diameter growth and bark production; denser stands are needed for good timber production.

Corrective pruning is necessary if the growing point of young plants has been damaged (e.g. by browsing) and multiple leaders have developed. Care should be taken to control erosion, especially when plantations are burnt (e.g. to promote regeneration). If properly managed, black wattle may help to enrich soil nitrogen as a result of rhizobial nitrogen fixation, and rehabilitate degraded lands.

Diseases and pests The most common disease of black wattle is black butt. The disease was first described early in the 20th century as part of the disease complex known as gummosis. Black butt may kill the tree but it also affects the yield and quality of the bark. Associated pathogens include *Phytophthora* spp. and *Botryosphaeria dothidea*. In Zimbabwe, black butt occurs mainly below 1250 m altitude. A serious disease of black wattle in South Africa is wattle wilt caused by *Ceratocystis albofundus*. In the humid tropics, most damage occurs from fungal attacks of *Armillaria*, *Corticium*, *Fomes* and *Phytophthora* spp. under conditions with more than 3000 mm annual precipitation.

In its native range, black wattle is not cultivated because of serious damage by indigenous insects including the fireblight beetle *Acacicola orphana* (synonym: *Pyrgoides orphana*); sometimes severe damage may occur in Brazil, too. In most tropical countries, disease and pest attacks are generally not serious, although attacks by various insects, including defoliators (e.g. wattle bagworm, *Chaliopsis junodi*), stem-borers (e.g. *Platypus solidus*), and caterpillars (e.g. wattle looper caterpillar, *Achaea lienardi*) may occur. In Zimbabwe and South Africa, the brown wattle mirid or froghopper *Lygidolon laevigatum* is the major pest affecting mainly young plantations. It attacks the growing point of the leading shoot and upper branches causing stunted growth and a witches-broom appearance. Black wattle is also attacked by cutworms (*Agrotis* spp.) and whitegrubs (Scarabaeid larvae, e.g. *Lepidiota mashona*).

Harvesting Plantations for tannin bark are usually harvested after (7–)8–10(–12) years, when trees are more than 18 m tall and have a diameter of at least 15 cm. The bark is harvested by ripping it at several points near the base of the stem with a hatchet or short iron bar flattened at the end; the loosened strips of bark are pulled from the stem. After stripping, the bark is cut to bundle length; in Zimbabwe this is about 1.2 m. Stripping is easiest during periods of active growth. In Zimbabwe, timber is windrowed for later recovery against pole orders, but much of it cannot be sold and is burnt during subsequent land preparation.

Yield In South Africa typical yields of fertilized plantations are 15–25 m³/ha per year of wood and 1.5–2 t/ha of dry bark. In tropical regions, and with good management, yields range between 25 m³/ha and 35 m³/ha per year of wood and from 0.9–2 t/ha of dry bark. At the best sites 60–65% of the yield consists of first grade bark from stems of at least 15 cm diameter, on poorer sites the proportion is only 40–50%.

Handling after harvest The harvested bark is either transported immediately or dried locally first. In South Africa all bark is delivered fresh to the mill. In Zimbabwe most bark is processed fresh, but bark harvested after the milling season is dried for processing during the next season. When dried bark is used, drying should be done in partial shade; the inner bark darkens if exposed to direct sunlight. The bark discolours if it is re-wetted after drying. To obtain good bark quality, kiln drying is practised sometimes. In Indonesia trials have been done on portable charcoal-burning drying kilns in which the bark can be completely dried in about 60 hours. During drying the bark curls inwards; these 'sticks' are bundled for transport. During processing, the bark may either be extracted or prepared for marketing as dry bark. Fresh bark is preferred for extraction. Dry bark is graded according to thickness, maturity, lightness of colour, absence of corkiness and freedom from mould. It is marketed as chopped bark, ground bark or sometimes as dust, in pressed bales or in bags.

Genetic resources It is thought that the seed used for black wattle plantations outside Australia originated from a limited part of the natural range. Germplasm collections exist at the CSIRO Division of Forest Research, Canberra, Australia and at the Institute for Commercial Forestry Research (ICFR), formerly the Wattle Research Institute (WRI), Pietermaritzburg, South Africa. Some provenance testing has been done, e.g. by the ICFR and in China, but further studies are needed.

Breeding Major breeding objectives are enhanced vigour, better bark quality and stem form, and resistance to pests and diseases. The emphasis in the breeding programme in South Africa has shifted from improved bark yield and quality to improved timber yield and quality with acceptable bark yield and quality.

Prospects Due to substitution of plastics for leather and the subsequent decline in the importance of tannin since the 1960s, black wattle cultivation has decreased in importance. However, due to the growing importance of renewable resources versus synthetic products made from oil-tar, leather and skins tanned with vegetable tannins are likely to regain some of their former economic importance. Black wattle is a potential substitute for synthetic tannins, which are widely used in the tanning industry although toxic for the workers and damaging the environment. More recently the demand for black wattle timber in South Africa, and for export, has led to the conversion of some eucalypt plantations to black wattle. Woodlots of black wattle are being planted by rural farmers in South Africa for fuelwood and as a source of building material. Black wattle is important because of its multipurpose functions and its adaptability to a wide range of ecological conditions, including degraded sites. Special consideration should be given to using black wattle for soil rehabilitation in local land use systems.

Major references Booth & Jovanovic, 1988; Dunlop & Hagedorn, 1998; Herbert, 1993; Hillis, 1997; Luyt, Mullin & Gwaze, 1987; Nakashima, Ge & Sakai, 1996; Ohara, 1994; Roux, Kemp & Wingfield, 1995; Santana, Baumann & Conner, 1996; Sherry, 1971.

Other references Berenschot, Filius & Hardjosoediro, 1988; Coster, 1939; Ferguson, 1948; Hannah, Fergus & Jones, 1977; Martin, 1994; Nixon, 1992; Roux, 2000; Roux et al., 1976; Salim et al., 2002; Turnbull, 1986; Wiersum, 1991; Wingfield et al., 1996.

Sources of illustration Lemmens & Wulijarni-Soetjipto (Editors), 1991.

Authors R.W. Dunlop

Based on PROSEA 3: Dye and tannin-producing plants.

ACACIA NILOTICA (L.) Willd. ex Delile

Protologue Descr. Egypte, Hist. nat.: 79 (1813).

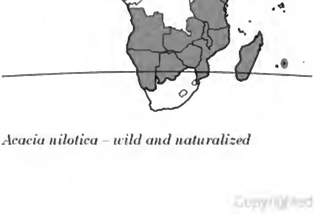
Family Mimosaceae (Leguminosae - Mimosoideae)

Chromosome number $2n = 52, 104, 208$

Synonyms *Acacia arabica* (Lam.) Willd. (1806), *Acacia scorpioides* (L.) W.Wight (1905).

Vernacular names Babul acacia (trade name), scented thorn, scented-pod acacia (En). Babla, gommier rouge, nebneb (Fr). Tchanga, goma da Índia (Po). Mjungu, msemehi, mgunga, mtetewe (Sw).

Origin and geographic distribution *Acacia nilotica* is native to the drylands of tropical Africa and western Asia, eastwards as far as India, Myanmar and Sri Lanka. In Africa it occurs from Senegal to Egypt and southwards through eastern Africa to Mozambique and South Africa (Natal) and the Indian Ocean islands. It has been distributed throughout the tropics and became naturalized in many areas, including Cape Verde, Jamaica, Nepal, Indone-



Acacia nilotica – wild and naturalized sia, Vietnam and Australia. It is widely cultivated in the Indian subcontinent.

Uses The pods of *Acacia nilotica* are used traditionally in Nigeria and other sub-Saharan countries for tanning leather and as a source of khaki-to-brown dyes if used without mordant, or grey and black dyes for cotton combined with a mordant of iron-rich mud. The latter process gives the typical dark grey stripes in the 'hile', 'sampak' and 'siole' traditional cotton textiles of Cameroon and in the 'langtang' traditional cotton weaving of the Mumuye of eastern Nigeria. These textiles were locally and regionally used as currency well into the 20th century and still have a great cultural importance. Now they are mostly used as presents from a man to his future wife and in major religious festivals, clan gatherings and funerals. Black dyes combining tannins most probably obtained from 'sant' (acacia pods) with iron mordants have been identified in ancient Egyptian textiles dating from the 18th Dynasty (1542–1305 BC) onwards. The dried mature pods used in local tanneries in Sudan produce a pinkish white leather of good quality. The tan stuff extracted from the pods is internationally called by its Hausa name: 'bagaruwa'.

In contrast in India and Pakistan it is the bark, a by-product from timber plantations, that is used for tanning and dyeing leather. The tannin produces a heavy leather which is firm, durable and hard, but combined with myrobalans (from *Terminalia* species) it produces excellent leather. Bark tannin is used especially in Bengal and Bangladesh for dyeing cotton and wool into various shades of brown and into black by combining it with a mordant of iron sulphide or iron-rich mud.

Acacia nilotica is a truly multipurpose tree, widely used as a timber, source of fodder, tannin and gum, and as a fence, shade and fuel tree. The dark brown heartwood is nearly twice as hard as teak and very shock resistant, and is used widely in constructions, for railway sleepers, mine props, tool handles and carts. The trees make effective live fencing, are a good host for the semi-parasitic sandalwood (*Santalum album* L.) and are important trees for lac insects (shellac) in the Indian subcontinent. Gum collected from the trunk and branches was formerly used in paints and medicines. It has properties similar to true gum arabic from *Acacia senegal* (L.) Willd. and is frequently used in calico printing and dyeing as a thickening agent. It is also used as sizing material for silk and cotton, and in paper manufacture in India. The leaves and pods are an excellent fodder, rich in protein. The flowers yield a honey of good quality. The Hausa people use roasted seeds as a food flavouring. In Tanzania the inner bark and the thick fruit pulp are boiled in water and drunk as a tea. In eastern Java (Indonesia) sprouted seeds are consumed as a vegetable, and well-roasted seeds are mixed with coffee. The bark of slender branches yields a fibre which is used for the manufacture of paper or is made into coarse ropes in India. In Africa twigs are used as a toothbrush. *Acacia nilotica* is also a popular ornamental avenue tree in India. The tannins contribute to its many medicinal uses, the plant acting as a powerful astringent. A decoction of the fruit is considered a febrifuge, and the seeds have antimalarial, antidiabetic, antihypertensive and antispasmodic activities. The pods have molluscicidal and algicidal properties, and are added to ponds in Sudan to kill snail species that carry schistosomiasis without affecting the fish. The bark, gum, leaves and pods are used in many traditional medicines, possessing anti-inflammatory properties.

Production and international trade In Africa production and trade in tannin, timber and other products of *Acacia nilotica* is important locally and nationally, but few products enter international trade to any extent and recent statistics for domestic consumption and exports are lacking. In India annual production of babul acacia bark for tannin was estimated in 1994 at 22,000 t, worth 1.2 million US$.

Properties In India tannin contents of entire pods of *Acacia nilotica* vary from 12–19% and from 18–27% after removal of the seeds. In Sudan de-seeded pods can reach tannin contents of up to 50%. Seeds are usually removed because of their high content of sugar-like components which tend to cause the tannin liquor to ferment. The pods produce a light-coloured, soft leather, ideal for book binding. Tannins from fallen pods are hydrolyzed in the soil to gallic and ellagic acids which are allelopathic to the herb layer. Two highly active flavanol molluscicides, epigallocatechin-7-gallate and epigallocatechin-5,7-digallate, have been isolated from pods. Bark of babul acacia constitutes one of the most important tanning materials of northern India; tannin content varies from 7–20% on a dry weight basis, with a tannin/non-tannin ratio of 1.5. The tannins, which belong to the proanthocyanidin type, increase in content in the bark as the trees age. The bark also contains colouring matters of the 'phlobaphene reds' type, giving a dark colour to the leather. Improved results for tanning leather are obtained by mixing bark with myrobalans (two parts to one) or controlling the pH of the tan liquor.

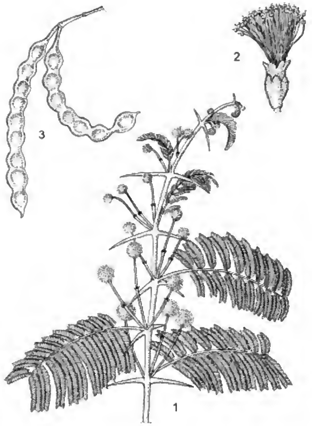
Tests in Kenya showed that the tannin contents of *Acacia nilotica* bark and bark extract are low (11.5–13% and 49.5–55%, respectively) in comparison to *Acacia mearnsii* De Wild. The tannins are less astringent and weakly binding, and penetrate hide rather extensively, leading to a comparatively soft product, which may however be brittle and non durable. Mixtures of an *Acacia nilotica* bark extract with the highly astringent bark extract of *Acacia senegal* in a ratio 3 : 1 give good results in tanning and may be used as a substitute for *Acacia mearnsii* bark extracts.

The wood is strong, tough and heavy, with a density of 650–830 kg/m^3 at 15% moisture content, but a density of 1170 kg/m^3 has been reported for wood of South African origin. At 15% moisture content, the modulus of rupture is 88 N/mm^2, modulus of elasticity 11,060 N/mm^2 and the compression parallel to grain 52.5 N/mm^2. The wood has a high content of silica which rapidly blunts cutting tools but is very durable if seasoned well. The wood is an excellent fuel, the energy value of moisture free heartwood being 20,710 kJ/kg. It yields a high grade charcoal with an energy value of 27,950–28,600 kJ/kg.

The nutritional composition of the leaves on dry weight basis is approximately: crude protein 13.9%, crude fibre 9.2%, N-free extract 69.8%, ash 7–10%, Ca 2.6%, Mg 0.4% and P 0.1% and their palatability is good. The pods are also used as fodder containing about 11–16% crude protein and 8–21% crude fibre, even though they also contain tannins. The seeds have low levels of the proteinase inhibitors trypsin and chymotrypsin.

The gum of *Acacia nilotica* varies in colour from very pale yellowish brown to dark reddish brown depending on the quantity of tannins in the sample. The lighter, more highly valued gums are soluble in water and very viscous; the tannins in the darker gum reduce the solubility. The gum has a moisture content of about 13% and is slightly dextrorotary. It is composed of galactoaraban which gives on hydrolysis L-arabinose, D-galactose, L-rhamnose, D-glucuronic acid and 4-O-methyl-D-glucuronic acid.

Description Single-stemmed, evergreen or deciduous tree up to 15(–25) m tall; root system deep and extensive; trunk straight, up to 100 cm in diameter; bark rough and longitudinally fissured, 1–1.5 cm thick, grey to brownish black, younger stems grey-brown and smooth; crown flattened or rounded; branchlets with paired stipular spines 1–5 cm long, straight but usually characteristically directed downwards. Leaves alternate, bipinnately compound, with 2–14 pairs of pinnae; petiole 0.5–2.5 cm long; rachis 1–10 cm long, with glands at the base of each pair of pinnae or top few pairs only; leaflets in 7–36 pairs per pinna, elliptical or narrowly oblong, 1.5–7 mm × 0.5–2 mm, rounded and oblique at base, apex obtuse, glabrous to pubescent. Inflorescence a globose head, 1–6 per leaf axil, with a pair of small bracts in basal half of peduncle; head c. 50-flowered. Flowers bisexual or male, 4–6-merous, bright or golden-yellow, sweetly scented; calyx lobes 1–2 mm long, glabrous or pubescent; corolla lobes 2.5–3.5 mm long, glabrous or pubescent; stamens numerous, free, up to 6 mm long, glandular; ovary superior, 1-celled, style long and slender. Fruit an oblong to linear, flattened pod, 4–22 cm × 1–2 cm, straight or curved, margins entire or deeply constricted between the seeds, the position of each seed clearly marked by a distinct raised bump in the



Acacia nilotica – 1, flowering branch; 2, flower; 3, fruits.
Redrawn and adapted by Iskak Syamsudin

pod valves, dark brown to grey, glabrous or velvety, indehiscent, 6–17-seeded. Seeds elliptical to circular in outline, flattened, 6.5–9 mm × 5–8 mm, dark brown to brownish black. Seedling with epigeal germination; cotyledons circular-ovate, stalked.

Other botanical information *Acacia* is a large pantropical genus, comprising more than 1300 species; most of them are found in Australia (more than 900), more than 200 in America, and about 130 in Africa. *Acacia nilotica* belongs to subgenus *Acacia*, which accommodates all the African *Acacia* species with straight spinescent stipules. Nine subspecies are distinguished in *Acacia nilotica* separated by pod and twig characteristics and tree shape. In tropical Africa the following 7 subspecies occur:

- subsp. *adstringens* (Schumach. & Thonn.) Roberty (synonym: *Acacia adansonii* Guill. & Perr.): young branchlets densely tomentose; pods not necklace-like, 13–21 mm wide, margins distinctly, often irregularly crenate, surface densely tomentose. In Africa from Senegal and Gambia to Somalia; also in western Asia to India.
- subsp. *indica* (Benth.) Brenan: similar to subsp. *nilotica* but the pods densely white-hairy. In Africa naturalized in Ethiopia, Somalia, Kenya, Tanzania and Angola; indigenous from Yemen to India and Myanmar, cultivated in Iran and Vietnam, and naturalized in Australia.
- subsp. *kraussiana* (Benth.) Brenan: similar to subsp. *adstringens* but pods with margins shallowly crenate, pubescent all over at first but the raised part over the seeds becoming glabrescent and shiny black when dry. From Angola and Tanzania to South Africa.
- subsp. *leiocarpa* Brenan: young branchlets glabrous to shortly hairy; pods not necklace-like, narrow (10–13 mm wide), margins straight or slightly crenate, almost glabrous. Restricted to coastal eastern Africa from Ethiopia southwards to Mozambique.
- subsp. *nilotica*: young branchlets glabrous to shortly hairy; pods necklace-like, narrowly and regularly constricted between the seeds, almost glabrous. From Mali and Burkina Faso to Sudan and Egypt; it has been cultivated in Tanzania, Iraq and the Arabian peninsula.
- subsp. *subalata* (Vatke) Brenan (synonym: *Acacia subalata* Vatke): similar to subsp. *adstringens* but pods with straight or only slightly crenate margins. In Africa in Sudan, Ethiopia, Somalia, Kenya, Uganda, Tanzania and Madagascar; possibly also in Pakistan, India and Sri Lanka.
- subsp. *tomentosa* (Benth.) Brenan: similar to subsp. *indica* but also young branchlets densely white hairy. Restricted to Africa, from Mauritania and Senegal to Sudan, Ethiopia and Egypt.

Subspecies with necklace-like pods (subsp. *indica*, *nilotica*, *tomentosa*) tend to be tall riverine trees or occur in seasonally flooded areas, while those with straighter margins to the pods (subsp. *adstringens*, *kraussiana*, *leiocarpa*, *subalata*) occur in drier sites. Occasionally intermediates between the subspecies are found and several questions about the pattern of variation within *Acacia nilotica* are still unsolved.

Anatomy Wood anatomical description:

- Macroscopic characters:
  Heartwood pale red to pinkish brown, often darkening upon exposure, distinctly demarcated from the yellowish white sapwood. Growth rings indistinct.

Growth and development *Acacia nilotica* is a pioneer species. A deep and extensive root system is formed on dry sites, the taproot developing first and then the laterals, which become compact and massive with age. On flooded sites however, the root system is largely lateral. *Acacia nilotica* nodulates and fixes nitrogen throughout its natural range and forms mycorrhizal associations with *Glomus* spp. It produces root suckers on rare occasions only. *Acacia nilotica* flowers at a relatively young age, around 3–4-years old under ideal conditions. Flowering is prolific and occurs on current-season growth mainly during the rainy season. If adequate moisture is available flowering can occur a number of times during the year.

Ecology *Acacia nilotica* is a tropical species, growing where average annual temperatures range from 15–28°C, being frost sensitive when young and withstanding daily maximum temperatures of 50°C. The mean maximum temperature of the hottest month is 25–42°C and the mean minimum temperature of the coldest month 6–23°C. It occurs from sea-level to over 2000 m altitude. *Acacia nilotica* prefers dry conditions, with an annual rainfall of (100–)250–1500(–2300) mm, however the extremes are only found under irrigation or where it is planted outside its natural range, e.g. in South-East Asia. In India the optimum lower rainfall limit is around 600 mm without irrigation. It occurs in both unimodal and bimodal rainfall regions with summer or winter regimes. Depending on the subspecies, it will tolerate both drought and flooded conditions for several months.

Acacia nilotica in Africa exhibits two very distinct ecological preferences. Subsp. *adstringens*, *leiocarpa* and *subalata* occur in wooded grassland, savanna and dry scrub forests on deep sandy to loamy soils, and also on lateritic and calcareous sites. Subsp. *kraussiana* also prefers dry grasslands and savannas, especially on compacted sandy loam, shallow granite or clay soils along drainage lines and rivers, but away from flooding. On the other hand, subsp. *nilotica* and *tomentosa* are restricted to riverine habitats and seasonally flooded areas on alluvial clay soils.

In the Indian subcontinent, subsp. *indica* occurs in dry forests at low altitudes, usually on alluvial soils subject to flooding or on black cotton soils. It is now widely planted on farms throughout the plains and will also grow on saline, sodic or alkaline soils and on soils with calcareous pans.

Propagation and planting *Acacia nilotica* can be easily propagated by seed. Trees produce seed in abundance from around 5–7-years old. Seeds can be extracted from the pods while seeds ejected by sheep during rumination or those from cattle and goat droppings may be collected. The latter seeds germinate easily due to fermentation and moistening. Seed weight varies from 6,600–11,600 seeds per kg. Germination capacity varies from 50–90%. Germination starts 1–3 weeks after sowing and is mostly complete in one month. Pre-sowing treatment is required once seed exhibits dormancy as the seed coat is very hard. Seed may be immersed in hot water (80°C) for about 30 minutes or in boiling water for 10–15 seconds and then soaked for 24 hours in cold water before sowing. Germination can also be improved by mechanical scarification, by soaking in concentrated sulphuric acid (90%) for 10–30 minutes followed by rinsing in cold water, and by fermentation in moist cow dung for 48 hours. Growth is rapid, and when planted in polytubes seedlings reach a height of 25–30 cm in 4 months. *Acacia nilotica* is selective in its association with *Rhizobium* and forms effective root nodules with only a few strains. Seed mixed with *Rhizobium* strain ANM 18 in a slurry and then sown in polybags has shown significantly increased seedling growth. Direct sowing in the field is the most common method of planting. Sowing in line with a seed rate of 1 kg/ha is recommended. For transplanted seedlings a spacing of 3 m × 3 m is common; when planted for the production of tannin and gum, a spacing of 4 m × 4 m is recommended.

Management Plantations of *Acacia nilotica* for timber, tannin or gum production require regular weeding and thinning to maintain maximum growth. Along the Blue Nile in Sudan, thinning begins from 4–5 years and continues in 3-year cycles. An ideal stocking density at 30 years is 100 trees/ha for 28 m tall trees and 400 trees/ha for 14 m tall ones. In old stands in Sudan, used for fuel wood extraction, there is evidence of adequate natural thinning and additional thinning seems not justified. Plantations in Sindh and Punjab (India) are irrigated at 3–7 day intervals after sowing, and 2–3 weedings are sufficient to control weed growth. Spot sowings with 10–15 seeds per hole did not require weeding, but needed early thinning and then thinning at 5-yearly intervals. For 5-year-old stands a density of 1200 trees/ha is recommended. Trees pollard well and can be freely lopped for thorn fences; however heavy lopping reduces tree growth. Use of NPK fertilizers did not prove economically worthwhile in plantations grown on a 20–25 year rotation.

Diseases and pests Several fungal diseases and insect pests attack *Acacia nilotica* but none limits its cultivation. *Fomes badius* and *Ganoderma lucidum* are the most damaging fungi, causing spongy rot, affecting the heartwood of the stem and branches of old trees. Removal of infected trees and sporophores, and improved soil aeration provide some protection. In India the beetles *Celosterna scabrator* and *Psiloptera fastuosa* are the most destructive insects. *Celosterna scabrator* is a root and stem borer, feeding on young bark. In Maharashtra, larvae are hand collected to reduce damage. *Psiloptera fastuosa* defoliates and gnaws the bark of thin twigs. Larvae of *Ascotis* sp., *Cusiala* sp., *Hyposidra* sp., *Pteroma* sp. and *Semiothesa* sp. defoliate the tree, larvae of *Argyroploce illepida* bore into the pods, grubs and adults of the weevil *Hypolixus truncatulus* damage seedlings and saplings. Seeds are often predated by bruchid beetles, that may destroy up to 70% of them. A dieback disease in Sudanese forests was due to a buprestid beetle. Powder-post beetles (*Sinoxylon* spp. and *Lyctus africanus*) attack the sapwood of felled timber. Wild animals, camels and goats can cause significant damage to the trees although light grazing by sheep may help to remove competing grass.

Harvesting Plantations of *Acacia nilotica* planted for timber and fuel wood production are usually harvested on a 10–20 year rotation with the bark as a useful by-product. In India the bark is separated from the logs by beating them with mallets. The strips are then sun-dried, chopped into small chips before being sent to tanneries. Bark from trees up to 10 years old yields a lighter tannin which is preferred in Pakistan. In sub-Saharan Africa, pods are collected for tanning, preferably from the tree and soon after turning black, to avoid mineral contamination from soil. Pods can be harvested at different ages to vary the colour of the tanned leather. In Sudan pods that have been lightly ground to remove seeds and fibrous matter, yield up to 60% tannin. For harvesting the gum, strips of bark 5–7.5 cm wide are removed from the trunk in the dry season, the bark around the cut is bruised with a hammer, and gum nodules form where the trunk has been damaged. Gum dries on contact with air and is collected a few days later.

Yield Productivities of plantations and natural stands of *Acacia nilotica* vary considerably with site conditions. Growth rate is relatively fast, with average timber yields for plantations on dry sites of 3–5 m³/ha per year using a 15–20 year rotation with 700–1000 trees/ha (10–12 m tall). Maximum yields of up to 9 m³/ha per year 10–15 years after planting have been obtained in Rajasthan and Uttar Pradesh (India). In the riverine forests of Sindh (Pakistan) a maximum mean annual increment of 13 m³/ha at 20 years, and 10.5 m³/ha at 30 years has been recorded. Estimates of standing biomass range from 36 t/ha for 5-year-old plantations to 307 t/ha for 17-year-old plantations in Haryana (India). In India 10-year-old trees yield about 35–40 kg bark, or about 6 t/ha, and plantations of about 600 trees/ha produce 12 t bark 15 years after planting. Average annual pod yield from the plantations is 8–10 t/ha. In Sudan individual trees yield 18 kg pods per year. Young trees in India yield annually 0.1–0.6 kg gum per tree, older trees yield less.

Handling after harvest Both pods and bark of *Acacia nilotica* are usually sun dried before being transported. To increase the tannin yield of the pods, seeds and fibrous matter are removed from them. Seeds may also provoke fermentation of the tannin due to their sugar content. In Sudan the traditional process for preparing leather is carried out in pots or waterproof pits in the ground of about 1 m in depth and diameter. Hides are first soaked in a river until they are completely clean, rehydrated and soft. Then they are plunged into a lime bath to destroy or soften the epidermis whereby also the hair or wool is loosened, and to destroy loose meat, sweat glands and blood vessels in the skin to facilitate the absorption of the tanning substances. Fresh hides are generally washed for about 2 hours, dry-salted hides 12–24 hours and flint-dried hides a little longer. In the bath the skins are stirred at least once a day. After this bath the skins are steeped in pigeon or dog dung for about 24 hours and then enter a tan bath with a solution prepared from babul pods (about 15 kg pods in 40 l water tan about 30 hides). This tanning takes 24–48 hours and the skins are stirred 4–5 times per day. After tanning the skins are first steeped in a saturated salt solution and then dried over a beam. The skins are softened by rubbing with a smooth stone or piece of wood. After drying the leather may be dyed. In Djibouti hides of goats to be used as water containers are tanned by simply filling the skins with crushed wet pods for 48 hours. Among the Hausa people in Nigeria, tanned hides are dyed into 'kuloko' black with a mixture of uncrushed 'sant' pods (*Acacia nilotica*) and blacksmith's iron refuse first steeped in water and left for several days to ferment and then concentrated by boiling and thickened with honey or sugar. The dye is applied with a piece of leather over the whole surface of the skin or in stencilled patterns. In Malawi dry pods are pounded and mixed with black ferruginous mud plastered on cloth to dye it black.

Genetic resources *Acacia nilotica* is very widespread and is not threatened. Subsp. *hemispherica* Ali & Faruqi however, endemic to a restricted area in Pakistan, could be under threat of extinction. *Acacia nilotica* is among a number of species selected by FAO/IBPGR in the late 1970s for exploration and conservation in arid zones. Some international collections were made from relatively few sites. Range-wide collections in Africa have been undertaken by the Oxford Forestry Institute (OFI, United Kingdom) and members of the African Acacia trials network (comprising OFI, CIRAD-Forêt and the Danida Forest Seed Centre-DFSC), co-ordinated by FAO. International provenance trials have been planted but these have yet to be evaluated. In India large provenance trials have recently been planted.

Breeding Most planting of *Acacia nilotica* is still based on seed from local provenances. In India data on germination, seedling growth and nitrogen fixation are available from recently planted provenance trials. Selection for products such as tannin or gum has not been undertaken. Isozyme banding patterns suggested that *Acacia nilotica* is autotetraploid, displaying tetrasomic inheritance. *Acacia nilotica* is self-compatible and approximately 60% of seeds are set through self-pollination.

Prospects *Acacia nilotica* is a very useful multipurpose tree and has been traditionally used and planted in Africa and Asia as a source of tannin, brown, grey and black dyes, gum, timber, fodder and fuel. The dyes and tannins extracted from the pods are excellent examples of renewable resources since they do not interfere with the plant growth. Being easy to propagate by seed, fast growing, nitrogen fixing, tolerant of poor soils and arid conditions it will always have a role to play in the reclamation of degraded areas where fuel and timber supplies are lacking.

Major references Brenan, 1983; Burkill, 1995; Fagg & Greaves, 1990; Imperial Institute, 1930; Lamb & Lamb, 1981; Mugedo & Waterman, 1992; Nonaka, 1989; Raymond, 1951; Sheikh, 1989; Wulijarni-Soetjipto & Lemmens, 1991.

Other references Adewoye & Rao, 1977; Anderson, Hirst & Stoddart, 1967; Arbonnier, 2004; Ayoub, 1985; CAB International, 2000; Dafallah & Al-Mustafa, 1996; Fagg, Barnes & Marunda, 1997; Gilani et al., 1999; Krishan & Toky, 1995; Luna, 1996; Mandal, Ennos & Fagg, 1994; Mohanty, Chandramouli & Naik, 1987; Nongonierma, 1976; Rao & Purkayastha, 1972; Singh, 1982; Tandon et al., 1988; Tindale & Roux, 1975; Troup & Joshi, 1983; Vantomme, Markkula & Leslie, 2002; Watt & Breyer-Brandwijk, 1962.

Sources of illustration Brenan, 1970.

Authors C.W. Fagg & James Z.A. Mugedo

ACRIDOCARPUS EXCELSUS A.Juss.

Protologue Ann. Sci. Nat., Bot., ser. 2, 13: 271 (1840).

Family Malpighiaceae

Vernacular names Mavoravo (En).

Origin and geographic distribution *Acridocarpus excelsus* is endemic to Madagascar, where it is widespread.

Uses The bark of *Acridocarpus excelsus* is collected from the wild, pounded fresh or dried and boiled for 2–3 hours. The decoction can be used to dye fibres deep red by simple immersion. The fibres can also be mordanted afterwards by steeping them in a solution of tamarind (*Tamarindus indica* L.) ash, which produces a fast red-brown. A decoction of the bark is used against diarrhoea and dysentery.

Properties The bark of *Acridocarpus excelsus* is rich in tannin and has astringent properties. The wood is red and hard.

Botany Deciduous shrub or small tree up to 15 m tall, with thick, grey, roughly fissured bark. Leaves opposite or alternate, grouped at the end of branches, simple and entire; stipules absent; petiole up to 1.5 cm long; blade lanceolate to obovate or elliptical, up to 8 cm × 3.5 cm, leathery, often silky pubescent below, pinnately veined with lateral veins in 7–12 pairs. Inflorescence a terminal raceme 2–7 cm long, 8–15-flowered. Flowers bisexual, zygomorphic, 5-merous; pedicel 1–2 cm long; sepals ovate-elliptical, up to 3.5 mm × 2 mm; petals unequal, elliptical, 6–11 mm × 5–7 mm, clawed, more or less curled and concave, margins fimbriate, yellow; stamens 10, unequal, filaments up to 2.5 mm long; ovary superior, globose, 3-celled, styles 2, up to 5 mm long. Fruit a samara up to 3 cm × 1.5 cm.

Acridocarpus comprises about 30 species, distributed in mainland Africa (23 species), Madagascar (4 species), the Arabian Peninsula, India and New Caledonia (each 1 species). Mainly based on differences in fruit and leaf characters, *Acridocarpus excelsus* has been subdivided into 4 subspecies, some with several varieties. It has the habit of an olive tree and is somewhat fire resistant. Most *Acridocarpus* species with a thick and tannin-rich bark are used against diarrhoea.

Ecology *Acridocarpus excelsus* occurs from humid littoral forest to dry deciduous forest and thickets. It is usually found on dry, rocky and sandy soils, from sea-level up to 1250 m altitude.

Genetic resources and breeding *Acridocarpus excelsus* is widespread in Madagascar and does not seem to be in danger of genetic erosion.

Prospects *Acridocarpus excelsus* as a source of red dye will remain only of some importance locally. However, the use of natural dyes in Madagascar is being revived to produce traditional textiles for the international market.

Major references Arènes, 1950; Decary, 1946; Etheve, 2005.

Other references Schatz, 2001.

Authors P.C.M. Jansen

ADENORANDIA KALBREYERI (Hiern) Robbr. & Bridson

Protologue Advances Rubiac. macrosyst. (Op. Bot. Belg. 6): 198 (1994).

Family Rubiaceae

Synonyms *Gardenia kalbreyeri* Hiern (1878), *Pseudogardenia kalbreyeri* (Hiern) Keay (1958).

Origin and geographic distribution *Adenorandia kalbreyeri* occurs from southern Nigeria to western DR Congo and northern Angola (Cabinda).

Uses A blue fluid is extracted from the fruit of *Adenorandia kalbreyeri*, which acts as a black cosmetic and as a tattoo dye. The plant has a high ornamental value as a climber with fragrant lily-like flowers.

Botany Scandent shrub or liana with stems over 6 m long. Leaves opposite, simple and entire; stipules 4–10 mm long, usually falling off; petiole 3–12 mm long; blade obovate, 7–24 cm × 4–10 cm, base cuneate to truncate, apex acuminate, pubescent below, pinnately veined with lateral veins in 8–15 pairs. Flowers solitary, terminal on lateral branches, bisexual, regular, 5-merous, very fragrant; pedicel up to 1 cm long; calyx tubular, 2–4 cm long, widening at apex with ovate-lanceolate lobes up to 2.5 cm × 1.5 cm, densely pubescent; corolla tubular, tube 10–16 cm long, lobes ovate to lanceolate, 4–8 cm × 2–4.5 cm, white, yellowish or greenish with red-purple streaks inside, pubescent; stamens inserted in the upper part of the corolla tube, sessile, anthers up to 3 cm × 3 mm; ovary inferior, 1-celled, style with glabrous columnar basal part and pubescent ellipsoid upper part up to 3 cm × 1 cm, shortly 2-lobed at apex. Fruit a leathery, almost globose berry up to 8 cm × 6 cm, with 10–12 longitudinal grooves and more or less persistent calyx tube, many-seeded. Seeds discoid.

Adenorandia comprises a single species and is classified in subfamily *Rubioideae*, tribe *Gardenieae*. It is closely related to the larger genera *Gardenia* and *Rothmannia*.

In Gabon the fruits of another Rubiaceous climber, *Aoranthe annulata* (K.Schum.) Somers (synonym: *Randia letestui* Pellegr.), also produce a black dye, which is similarly used.

Ecology *Adenorandia kalbreyeri* occurs in primary as well as secondary rain forest, often in forest edges, also in secondary regrowth in abandoned cultivation areas.

Genetic resources and breeding *Adenorandia kalbreyeri* is rather widespread and does not seem to be in danger of genetic erosion.

Prospects *Adenorandia kalbreyeri* will remain of minor importance as source of a dye. Its phytochemistry in relation to its dyeing properties, as well as its ornamental potential deserve more attention.

Major references Burkill, 1997; Hallé, 1970; Raponda-Walker & Sillans, 1961.

Other references Robbrecht & Bridson, 1993; Somers, 1988.

Authors P.C.M. Jansen

ALECTRA SESSILIFLORA (Vahl) Kuntze

Protologue Revis. gen. pl. 2: 458 (1891).

Family Scrophulariaceae (APG: Orobanchaceae)

Origin and geographic distribution *Alectra sessiliflora* is widespread and found all over tropical Africa and subtropical southern Africa, through the Indian Ocean islands to tropical Asia.

Uses The yellow to orange flowers and roots (haustoria) of *Alectra sessiliflora* have been used by rural people in South Africa to dye cloths and other textiles. In DR Congo a golden yellow dye is extracted which is used for colouring wood. In traditional medicine in Tanzania leaf sap is taken to hasten childbirth and plant ash mixed with castor oil is rubbed onto scars caused by leprosy. A root decoction is used as a mouthwash against toothache and given to small children to treat diarrhoea. In DR Congo macerated fresh plants are eaten by pregnant women as a galactagogue, and a leaf decoction is used against kwashiorkor (severe malnutrition in children resulting from a diet excessively high in carbohydrates and low in protein).

Botany Erect, annual herb up to 60 cm tall, with straight, simple or branched, hairy stem. Leaves opposite, simple; stipules absent; petiole up to 3 mm long; blade circular to ovate or lanceolate, 1.5–5.5 cm × 1–3 cm, base cuneate, rounded or cordate, apex acute or obtuse, margin almost entire to coarsely toothed, rigid-hairy to almost glabrous. Flowers solitary in axils of upper leaves, bisexual, slightly zygomorphic, sessile or with pedicel up to 0.5(–1.5) mm long; bracteoles linear to filiform; calyx campanulate, 6–8 mm long, 10-veined, 5-lobed with triangular lobes 3–5 mm long; corolla campanulate, slightly longer than calyx, pale yellow to dull orange, sometimes with reddish veins, withering but not falling off; stamens 4, 2 longer ones with long-hairy filaments; ovary superior, glabrous, 2-celled, style clavate above the middle, recurved, included with stamens in corolla. Fruit a globose capsule c. 5.5 mm in diameter, glabrous, many-seeded. Seeds linear to clavate, small.

Alectra comprises 30–40 species and is distributed pantropically, with about 30 species in tropical Africa. *Alectra sessiliflora* is very variable and might turn out to be a complex of species. Three varieties have been distinguished, mainly based on differences in leaves and in degree of pubescence of several parts.

Alectra sessiliflora is a hemiparasitic weed on the roots of *Asteraceae*, grasses and a number of crops (e.g. groundnut, maize, sugar cane). Seeds require a chemical stimulant from the host roots in order to germinate. The temperature also plays an important role for successful germination. *Alectra sessiliflora* is at least partly dependent on the host for minerals and water, and it can become a serious pest in crops.

Ecology *Alectra sessiliflora* is found in grassland and cultivation areas, from sea-level up to 2500 m altitude.

Genetic resources and breeding *Alectra sessiliflora* is very widespread and not in danger of genetic erosion.

Prospects Most probably *Alectra sessiliflora* will remain only very locally of some importance as a dye source. Its medicinal properties need further investigation for evaluation.

Major references Burkill, 2000; Philcox, 1990; van Wyk & Gericke, 2000.

Other references Chifundera, 2001; Haerdi, 1964; Hepper, 1960; Hepper, 1963; Kokwaro, 1993; Neuwinger, 2000; Van der Merwe, 1993.

Authors P.C.M. Jansen

ALOE ZEBRINA Baker

Protologue Trans. Linn. Soc., ser. 2, Bot. 1: 264 (1878).

Family Asphodelaceae

Vernacular names Zebra leaf aloe, spotted aloe (En). Aloès zébré, aloès tacheté (Fr).

Origin and geographic distribution *Aloe zebrina* is widespread in southern Africa, from Angola, through Namibia, Botswana and Zimbabwe to Mozambique.

Uses Particularly in north-western Botswana (Ngamiland), but also elsewhere in its distribution area, the roots of *Aloe zebrina* are among the main dyes for the *Hyphaene* palm fibres used in basketry weaving to which they give a golden-yellow colour. They have been adopted for wool dyeing by European settlers who introduced the use of metallic mordants such as alum to obtain more intense, fast colours. Other uses include the making of cakes with the boiled and pressed flowers among the people along the Kunene river in Angola. Medicinally, a decoction of the powdered stem and leaf bases is taken orally twice a day by women after delivery to cleanse the system. The (bitter) juice of many *Aloe* species is used as a powerful purgative and worm expellant, as disinfectant for wounds, and to treat skin problems including conjunctivitis. Like many *Aloe* species *Aloe zebrina* has ornamental value and potential for cultivation in arid to semi-arid, frost-free locations. Seed is readily available from specialist suppliers.

Properties The yellow leaf sap of most *Aloe* species contains anthrone C-glycosides such as aloin and homonataloin, and the yellow root sap anthranoid aglycones such as chrysophanol (a fast orange-brown colorant) and asphodeline. The roots of *Aloe zebrina* (and *Aloe parvibracteata* Schönl.) further contain aloesaponarin, aloesaponol and related compounds of the 1-methyl-8-hydroxyanthraquinone pathway. Moreover, isoleutherol is a unique chemical compound found in the roots of spotted aloes.

Botany Succulent herb up to 160 cm tall, without stem or with a short stem up to 30 cm long, freely suckering and forming dense groups, with yellowish leaf sap. Leaves 15–25, densely clustered into a rosette, without petiole, linear-lanceolate, 15–30 cm × 6–7 cm, fleshy, upper surface rather flat, powdery-glaucous, striate and marked with large oblong whitish spots more or less arranged in a series of irregular transverse bands, lower surface convex, very powdery-glaucous, margins armed with stout, horny, deltoid, brown-tipped teeth 6–7 mm long, 10–16 mm distant. Inflorescence with stalk copiously branched above the middle, the branches terminating in lax racemes 30–40 cm long; bracts linear-lanceolate, c. 1 cm long. Flowers bisexual, regular; pedicel 6–7 mm long; perianth tubular, 3–3.5 cm long, 6-lobed, dull red, much inflated around the ovary, 3 outer lobes acute, many-veined, 3 inner lobes more obtuse and wider; stamens 6, included; ovary superior, 6-grooved, 3-celled, style filiform, stigma headlike. Fruit a capsule, dehiscing loculicidally, many-seeded. Seeds c. 7 mm long, broadly winged, dark coloured, punctate.

Aloe comprises about 330 species, of which about 275 occur in mainland Africa, 40 in Madagascar and 15 in Arabia. *Aloe zebrina* is variable. In its natural distribution area it flowers mostly between February and April, some types in June–July.

The group of aloes to which *Aloe zebrina* belongs (called spotted or maculate aloes) is characterized by relatively small, usually stemless rosettes, spotted leaves and swollen flower bases. Since the species within this group are very similar it seems likely that the roots of almost all of them are suitable as a source of dye. Examples are *Aloe cryptopoda* Baker, found in Malawi, Botswana, Zimbabwe, Mozambique and South Africa, the roots of which dye wool red-brown to purplish-red, depending on the mordant; *Aloe marlothii* Berger, found in Botswana, Mozambique, South Africa and Swaziland, the roots of which dye yellow; and *Aloe parvibracteata* Schönl., found in Mozambique, South Africa and Swaziland, the roots of which dye yellow. The leaves of several less closely related *Aloe* species can also be used for dyeing, e.g. those of the South African species *Aloe speciosa* Baker give a beautiful delicate pink colour to wool, even without mordants, and those of *Aloe succotrina* All. shades of reddish-purple. Several species growing in Ethiopia (e.g. *Aloe steudneri* Schweinf., *Aloe percrassa* Tod.) give red dyes.

Ecology *Aloe zebrina* is found in dry thickets and marshy meadows on river banks.

Management *Aloe zebrina* suckers freely and can form dense groups, although differences exist between populations. Its roots can easily be collected on a sustainable basis because the plants easily form new roots, provided they are left to grow again. For dyeing *Hyphaene* palm fibres, the roots are collected from the wild, preferably on a small scale, and boiled with the weaving material until a golden-yellow colour is obtained. In Ethiopia, the leaves of *Aloe* sp. ('sete ret') are chopped and boiled in water with white cloth until it is dyed red.

Genetic resources and breeding *Aloe zebrina* is quite widespread in southern Africa, but is, like all *Aloe* species, protected against collection and trade from the wild by CITES regulations. In South Africa several germplasm collections are available in botanical gardens.

Prospects *Aloe zebrina* will remain only locally important as a dye plant. The ornamental value of all aloes will remain of major economic importance.

Major references Reynolds, 1982; Tournerie, 1986; Schweppe, 1993; van Wyk & Gericke, 2000.

Other references Watt & Breyer-Brandwijk, 1962.

Authors P.C.M. Jansen

ANOGEISSUS LEIOCARPA (DC.) Guill. & Perr.

Protologue Fl. Seneg. tent.: 280, t. 65 (1832).

Family Combretaceae

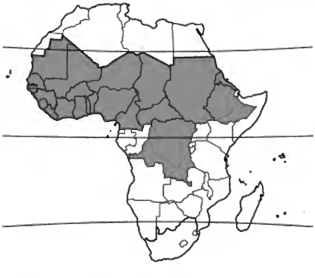
Chromosome number $2n = 24$

Synonyms *Anogeissus schimperi* Hochst. ex Hutch. & Dalz. (1927).

Vernacular names N'galama, African birch (En). N'galama, bouleau d'Afrique (Fr).

Origin and geographic distribution *Anogeissus leiocarpa* occurs from Senegal to Eritrea and Ethiopia, south to DR Congo. In Benin the tree is occasionally planted near villages for its dye and in Burkina Faso and Mali plantations have been planned.

Uses In West Africa, the leaves are used in the oldest African traditional dyeing process of cotton textiles known as 'basilan', a term particularly used by the Bambara and Malinké of the Mandé group of people. In general the Mandé people first weave cotton into rather narrow strips of cloth which are sewn together in larger units that are used to make clothes. Basilan, a Bambara word, means 'serving to obtain a result', referring in this case to a plant which serves for colouring. Cloth dyed with a decoction of the plant is called 'basilanfini', 'fini' meaning 'cloth, textile'. The colouring agents of plant origin used in basilan dyeing impart a yellow, ochre or ochre-red colour to cotton and as the plants used are rich in tannins they also play a role as mordants. Dyers of the Sénoufo people of Mali and northern Côte d'Ivoire use decoctions of leaves of *Anogeissus leiocarpa* (n'galama), *Terminalia macroptera* Guill. & Perr. (wôlô, *Combretaceae*), *Lannea microcarpa* Engl. & K.Krause (n'peku, *Anacardiaceae*) or *Sorghum bicolor* (L.) Moench (ga-



Anogeissus leiocarpa – wild

jaba, a cultivar with red leaves, *Poaceae*), to which sometimes traditional potash or ash obtained from the leaves of *Adansonia digitata* L. (baobab, *Bombacaceae*) is added, as a dye bath for the traditional 'red cloth of Korhogo'. The Hausa people of northern Nigeria use the leaves of *Anogeissus leiocarpa* similarly. In Mali cotton cloth dyed yellow or ochre-yellow with *Anogeissus leiocarpa* and *Terminalia macroptera* is used particularly to dress newly circumcised boys and excised girls because of its antimicrobial activity. The dress of 'wisdom holders' (hunters, seers, mask masters) is generally coloured ochre-red with *Lannea microcarpa* on a yellow background made with *Anogeissus leiocarpa*. Since 1990, the local and international success of basilan textiles has led to the development of a modern basilan industry thanks to the innovative efforts of the N'domo ('Centre for the Conservation of Traditional Arts', branch of the Kasobané Group in Ségou, Mali).

'Bogolan' is another traditional dyeing technique, developed from basilan, and deeply rooted in Mali. 'Bogo' means 'earth, mud', so bogolan means 'obtaining a result with mud' and 'bogolanfini' 'cloth dyed with mud'. In this technique a pattern is drawn with iron-rich mud on a background dyed first using the basilan technique. The mud reacts with the basilan dye creating a black colour. Several bogolan styles exist. Bambara people draw the patterns with mud and these turn black when they react with the basilan-impregnated cloth. Sheyna people (Korhogo, Côte d'Ivoire) do it the other way round; they first draw the design with basilan, usually passing several layers of the decoction over the lines and surfaces of the pattern and then they either draw again on the designs with a last layer of liquid mud applied with a brush made of palm-tree stem or they plunge the whole cloth into a bath of diluted mud. Where the mud comes into contact with the design traced with basilan on the tissue, black patterns are formed and fixed into the cloth while the mud washes out from the rest of the surface, leaving a white ground in the natural colour of cotton. The designs obtained on bogolan bear special meanings or messages, and the most elaborate compositions are found in Mali in the regions Bélédougou (Kolokani), Fadougou (Banamba), Pondo (south of Djenné) and Bendougou (Bla). In these regions it is mostly the women who practise the bogolan technique, following the ancient procedures inherited from their ancestors. The themes of the designs, especially those of the loincloths from these districts, relate to local cultures and communities, their history, fashions, myths, family events, the hierarchy of social groups, and some are also endowed with protective powers. This dyeing technique, formerly only applied by women on special family occasions, has evolved during recent years to become an important branch of the craft economy in Mali. Dyeing with *Anogeissus leiocarpa* has even become a full-time occupation for many people.

The bark, leaves and roots of *Anogeissus leiocarpa* also serve for traditional tanning of hides to leather, particularly those of goats in parts of northern Niger. The leaves colour the leather yellow. The bark yields a gum used in leather-working because of its adhesive properties. The ash of the leaves and the bark are used as mordants to improve the fastness of many other dyes and in the indigo dyeing process to maintain the necessary alkaline pH. The leaves are sometimes used as fodder for small ruminants.

The wood of *Anogeissus leiocarpa* is an excellent fuel and yields good charcoal. In the whole Sahel region fuel has become so scarce that even these useful trees are being sacrificed. The wood, called 'kane' in trade, is hard and much used for piles and rafters in house construction, for agricultural implements, tool handles and occasionally in cabinet making. In 2002 the Ministry of Economic Affairs in Mali encouraged wood carvers to use local instead of imported wood, which further increased the use of *Anogeissus leiocarpa* wood. Woodash from this tree is used in northern Nigeria to dehair skins in preparation for their tanning.

The bark, leaves and roots are used in traditional medicine for humans and animals. They have antimicrobial and anthelmintic activity and are usually taken as decoctions. A decoction of the leaves or leafy twigs is used against yellow fever, jaundice, different kinds of hepatitis, common cold and headache. In Burkina Faso powdered bark and a bark decoction are used to treat wounds, eczema, psoriasis, anthrax, carbuncles, boils and several kinds of ulcers. The bark decoction is also known as a muscular tonic. In Niger a leaf decoction is applied against haemorrhoids and skin diseases. The bark and the exuding gum prevent and cure dental caries and toothache and are commonly used in Africa. The gum, fairly soluble in water, is chewed and in northern Niger it is considered the best chewing gum substitute for gum arabic. In Ghana and Nigeria the roots are used and traded as chewing sticks. In Côte d'Ivoire the fleshy roots are used against labour pains and in Burkina Faso to accelerate wound healing. The seeds have a wide bactericidal and fungicidal activity in humans and animals. *Anogeissus leiocarpa* is a graceful ornamental avenue and shade tree of the drier regions and could also be used for reforestation. In Eritrea it is planted to stabilize river banks. In Burkina Faso *Anogeissus leiocarpa* is a highly esteemed and respected holy tree, named 'siiga', meaning 'the soul'.

Production and international trade Traditional bogolan cloth started being commercialised on a fairly small scale in Mali in the 1970s, mostly by women from the districts Kolokani, Banamba, San, Djenné and Ségou who were seeking to increase the family income. This commercial development really started to become more important in the 1980s, and since then several centres of big scale bogolan cloth production have emerged, e.g. the town of San. Between 1980 and 2004, trade in clothes and hangings decorated in the bogolan technique has boomed and these textiles are now exported in large quantities all over the world. The craft is most thriving in Mali, where Bamako and Mopti have become commercial centres for the export of bogolan cloth to Senegal, Ghana, South Africa, Europe (France, Germany, Switzerland, Belgium), Asia (Japan) and America (United States, Canada). The bogolan industry has spread to neighbouring countries; after Mali, Burkina Faso and more recently Senegal. Côte d'Ivoire and Niger have also started producing bogolan cloth on a large scale.

In the early 1990s it became fashionable in Mali to wear cotton clothes decorated using the bogolan technique. So production for local use was added to export production and at present in the town centres many women's associations practise bogolan dyeing as a source of professional income, which is also attracting more and more male craftsmen.

Bogolan cloth production and trade requires the harvesting and processing of huge quantities of leaves of *Anogeissus leiocarpa*. In Ségou, an important workshop where 15 artists work used about 1500 kg of dry leaves in 2004, allowing more than 5000 m^2 (or 1800 kg) cloth to be dyed. The total demand for leaves in Ségou is estimated at 6000 kg, corresponding to more than 20,000 m^2 dyed cloth. During recent years Bamako exported about 520 t of dyed cloth annually. This corresponds with 430 t dried leaves, estimated to be about 20% of the total quantity used in Mali.

Bark of *Anogeissus leiocarpa* has been exploited for cosmetic purposes in Burkina Faso since 2000, initiated by the French cosmetic industry in collaboration with the population of Koro village. A plantation of 1800 trees (5 ha) is being planned for the production of bark to supplement production from wild trees.

Properties The leaves of *Anogeissus leiocarpa* contain ellagic, gallic and gentisic acids, derivatives of gallic and ellagic acid and several flavonoids (derivatives of quercetin and kaempferol). The high concentration (up to 17%, based on dry matter) of hydrolysable tannins (gallic and ellagic acid derivatives) explains the usefulness of *Anogeissus leiocarpa* in the bogolan technique. Cloth impregnated with the leaf extract helps to fix other colours (e.g. the brown-red obtained by the bark of *Lannea microcarpa*), *Anogeissus leiocarpa* acting as a very efficient mordant on cotton for other natural dyes.

The majority of the medicinal uses of *Anogeissus leiocarpa* are likely to be based on its tannin content. No experimental data on their non-toxicity appears to have been published but the popular use of giving the bark decoction to drink to new-born infants is of interest in this connection.

The bark contains nearly no flavonoids but is rich in derivatives of ellagic acid (2.5–5% of the dry matter) and contains the polyalcohol sorbitol, terpenoids (α-amyrin, β-amyrin and β-sitosterol) and traces of alkaloids. Six molecules of ellagic acid derivatives were observed and four of them were isolated and characterized. These molecules are 3,3',4'-tri-O-methylflavellagic acid, 3,3'-di-O-methylellagic acid, tri-O-methylellagic acid and 3,3'-di-O-methyl-4-β-O-xylopyranosyl-ellagic acid. These derivatives are good antioxidants acting as scavengers of free radical oxygen and as protectors of DNA from injury by alkylating agents. They are anti-inflammatory and anti-allergic agents and have anticarcinogenic and antimutagenic activities. Research has shown that the ellagic acid derivatives show an inhibition of certain enzymes of the metalloproteinase type in several types of cellular skin cultures and retard the degradation of collagen. This research resulted in the elaboration of a substance named 'anogelline' which is now used in some cosmetic skin creams made in France.

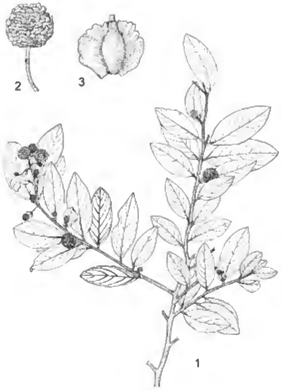
Extracts of stem and root bark and of the leaves showed antifungal activity against a number of pathogenic fungi. Moderate antibacterial activity of the bark was also demonstrated. Chewing sticks made of *Anogeissus leiocarpa* showed strong activity against a wide spectrum of bacteria, including some contributing to tooth-deterioration. *Anogeissus leiocarpa* extracts exhibited in-vitro activity against chloroquine-resistant *Plasmodium falciparum* strains.

The gum of *Anogeissus leiocarpa* contains amino acids (glutamic acid, aspartic acid, alanine, glycine) as well as 20% of a polysaccharide. On hydrolysis the polysaccharide gives 12% D-xylose, 32% L-arabinose, 5% D-galactose, 2% D-mannose and 20% oligosaccharides (with traces of rhamnose, ribose and fucose).

The wood is heavy and hard. The heartwood is dark brown to black and distinctly demarcated from the whitish yellow sapwood. The density is 720–1200 kg/m^3 at 15% moisture content. The grain is wavy or interlocked, texture fine. The shrinkage rates are small. The wood air-dries slowly but easily, and kiln drying is rapid. Slight checking and end splitting may occur, as well as moderate bending and twisting. The wood is moderately easy to saw, but difficult to plane, mortise and bore. It finishes and polishes well and is easy to turn and glue, but nailing is difficult. It is rather resistant to powder-post beetles and termites, but not to marine borers. It is extremely resistant to preservatives.

Adulterations and substitutes In regions where *Anogeissus leiocarpa* is rare or absent, two other plant species can be used as a substitute for the bogolan technique. The leaves of *Combretum glutinosum* Perr. ex DC. (tyangara, cangara, *Combretaceae*) can be used or, when these are not available, the twigs of *Hexalobus monopetalus* (A.Rich.) Engl. & Diels (fuganyé, *Annonaceae*). Although these two species are less appreciated than *Anogeissus leiocarpa*, they can be used in a similar way for dyeing. The leaves of *Combretum glutinosum* contain ellagic and gallic acid derivatives and flavonoids like *Anogeissus leiocarpa* while the chemical components of *Hexalobus monopetalus* are different.

Description Evergreen shrub or small to medium-sized tree up to 15(–30) m tall, with straight, slightly grooved bole up to 1 m in diameter and open crown with gracefully drooping, pubescent branches; bark grey to mottled pale and dark brown, scaly, flaking off in rectangular patches, fibrous, exuding a dark gum.



Anogeissus leiocarpa – 1, flowering branch; 2, infructescence; 3, fruit.
Redrawn and adapted by Iskak Syamsudin

Leaves alternate to nearly opposite, simple and entire; stipules absent; petiole 1–6 mm long; blade ovate to elliptical or ovate-lanceolate, 2–10 cm × 1–4 cm, base cuneate or obtuse, apex obtuse or acute, densely silky hairy when young, lateral veins in 4–8 pairs, prominent beneath. Inflorescence an axillary or terminal, usually solitary globose head 0.5–2 cm in diameter; peduncle up to 2.5 cm long, bearing 2 pairs of deciduous bracts. Flowers bisexual, regular, 5-merous, pale yellow, fragrant; receptacle stalk-like, 3–4 mm long; sepals connate into a lobed campanulate cup c. 1 mm high; petals absent; stamens 10, filaments filiform, c. 3 mm long, anthers cordate; ovary inferior, 1-celled, rusty hairy above the middle, style simple, filiform. Fruit a rounded samara 4–10 mm × 6–11 mm × 2–2.5 mm, with 2 wings, yellowish to reddish brown, shortly beaked, 1-seeded, packed horizontally into dense cone-like infructescences 1–2 cm in diameter. Seed ovoid-fusiform, c. 3 mm × 2 mm.

Other botanical information *Anogeissus* comprises 8 species, 5 of which occur in tropical Asia, 2 in Arabia and 1 in tropical Africa. The genus seems most closely related to *Conocar-*

pus, which differs by its flower heads arranged in panicles, usually 5 functional stamens and fruits without beak.

Indian sumach (*Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guill. & Perr.) contains tannins and flavonoids similar to those of *Anogeissus leiocarpa* and is similarly used for tanning hides and dyeing textiles in India, Sri Lanka and Nepal.

Growth and development The germination of *Anogeissus leiocarpa* seeds takes a long time and seedlings are not easy to obtain. Once established the plant is slow growing. Normally the tree is evergreen, but due to bush fires (October–November) it can stay without leaves for several weeks. Flowering is year-round but most abundant at the beginning of the rainy season between January and April. The flowers have a strong sweet smell. Fruiting is most abundant between March and May. The infructescences disarticulate when they become dry and the winged fruits are easily dispersed by wind.

Ecology *Anogeissus leiocarpa* is found from the driest savanna to the wetter forest borders, in wooded grassland and bushland and on riverbanks where annual rainfall is 200–1200 mm. It often grows gregariously on fertile soil in moist situations, from sea-level up to 1900 m altitude.

Propagation and planting Propagation is by seed, which is light with 140,000–150,000 seeds/kg. Seeds soon lose their viability (within 6 months) and their germinating capacity is rather low. Up to now *Anogeissus leiocarpa* is mainly harvested from the wild, but in Mali and Burkina Faso commercial cultivation has started (e.g. a plantation of 5 ha is present in Koro, Houet Province, Burkina Faso).

Management *Anogeissus leiocarpa* can be pollarded and the tree has some ability to coppice. It is very sensitive to fire.

Diseases and pests *Anogeissus leiocarpa* is a hardy tree species and no serious diseases or pests are known.

Harvesting Harvesting of the leaves at the beginning of the flowering period (January–February) is preferred, but because the tree is evergreen, they can be harvested any time of the year. The best period to harvest the bark is at the end of the dry season, from the end of March until the beginning of June, both because of the availability of manpower and of the optimum concentration and condition for exploitation of the active principle anogelline present in the bark. In Burkina Faso 'good harvesting practices' for harvesting bark as issued by the National Forestry Department should be followed to limit the damage to the trees: they include instructions for the use of adapted utensils and rules for the maximum quantity of bark that can be harvested (1–1.5 kg fresh bark per tree, corresponding to 0.5–1 kg dry bark). For every harvest a 'harvest authorisation', issued by the Regional Environment Direction, is needed, for which tax has to be paid. Material for export is strictly controlled and needs a phytosanitary certificate.

Yield The annual yield of dry leaves is estimated to be 20–25 kg/tree and of dry bark 0.5–1 kg/tree. Total annual yield of dry leaves in Mali for bogolan utilisation is estimated to be about 2000 t from 100,000 trees.

Handling after harvest The production of a bogolan cloth is a 4-step process. First comes the preparation of the iron-rich mud. This is done about 2–4 weeks before use. The mud is collected from the banks of certain rivers, lakes or ponds and kept in a container. It is stirred from time to time, adding a bark decoction of *Terminalia macroptera* or *Piliostigma reticulatum* (DC.) Hochst. (nyama, *Caesalpiniaceae*). Then the cloth is dyed using the basilan technique, using the leaves of *Anogeissus leiocarpa* and sometimes *Lannea microcarpa* bark. To prepare the dye bath the leaves are either put in water in a large cooking pot with a small amount of baobab ash-lye added and boiled, or the leaves are just soaked in water without heating for 2 days. The latter way is preferred in Ségou (Mali) because the result is as good and no fuel is needed. The cloth to be dyed is soaked in the bath and subsequently dried in the sun. Soaking and drying is repeated several times to obtain a deeper colour, taking care that the same side of the cloth is always exposed to the sun. The third step consists of drawing the design on the cloth with the prepared mud, using an iron tool ('binyéni') or a pen made out of a *Borassus* leaf stalk ('kala'). The black designs on the cloth are created by the iron salts present in the mud that react with the yellow or ochre-red basilan dyes rich in hydrolysable tannins. The mud can be applied several times to obtain a very deep black. Eventually the cloth is dried, cleaned and washed. The dry mud sticking to the cloth is removed by washing in a river; when water is scarce the mud is first removed by rubbing and shaking and then the cloth is washed with clean water. After drying again, the bogolan cloth is ready.

In the bogolan technique the bark of *Launea microcarpa* is sometimes used to obtain different colours. If a uniform orange to red-brown colour is required for the background, the whole textile can be soaked in the *Launea* bark decoction. Mud is then applied to the cloth to decorate it with black designs. This can also be repeated several times to obtain a true black. Dyeing with *Launea* gives reddish colours and *Anogeissus* gives yellow colours.

Genetic resources No germplasm collections of *Anogeissus leiocarpa* are known. In regions where *Anogeissus leiocarpa* is collected, the harvesting contributes to the growing scarcity of the tree populations, also because little rejuvenation appears to be taking place. Formerly *Anogeissus leiocarpa* occupied whole forests on fertile soils. At present, *Anogeissus leiocarpa* is becoming rarer because land is being cleared for agriculture, wood is collected for timber and fuel and the seeds are difficult to germinate.

Prospects At present, dyeing with vegetable dyes, mainly based on the use of *Anogeissus leiocarpa* leaves, meets the international demand for natural products, allowing whole families, among which many young people, to earn a living. Taking into account the importance of *Anogeissus leiocarpa* in the success of this type of textile production and trade (the whole cotton industry benefits from the export of bogolan cloth), and because most workshop owners have transmitted their know-how and trained a generation of young people, it is urgent to ensure a continuing supply of this tree for the coming years. This can be done in two ways. First, through careful management of wild populations of *Anogeissus leiocarpa*: a similar protection policy as the one applied in Mali for some other useful tree species (e.g. baobab, shea butter tree) could be extended to this species. A second possibility is cultivation of *Anogeissus leiocarpa*. In addition to the plantations that have been established in Burkina Faso, propagation trials to renew old populations are being carried out and paid for by some dyer artists in Ségou (Mali). Such initiatives deserve support and should be undertaken on a much larger scale. However, long-term investments are difficult to plan, owing to the fluctuating nature of international fashion trends.

Major references Arbonnier, 2004; Burkill, 1985; Cardon, 2003; Duponchel, 2004; Irvine, 1961; Kerharo & Adam, 1974; Liben, 1983; Malgras, 1992; Neuwinger, 2000; Scott, 1978.

Other references Adam, Echard & Lescot, 1972; Adjanohoun, 1986; Aubréville, 1950; Bamidele Sanni & Okor Dorcas, 1983; Batawila et al., 2005; Bhatt & Saxena, 1979; Bouquet & Debray, 1974; Cozzi et al., 1995; Dalziel, 1937; Govindarajan et al., 2004; Keay, 1954a; Majid et al., 1987; Nacro & Millogo-Rasolodimbi, 1993; Nduji & Okwute, 1988; Osawa et al., 1987; Smart et al., 1986; Somé, Sawadogo & Chauvel, 1983; Taiwo, Xu & Lee, 1999; Viron-Lamy et al., 2001; Vonthron-Sénécheau et al., 2003.

Sources of illustration Liben, 1983.

Authors C. Andary, B. Doumbia, N. Sauvan, M. Olivier & M. Garcia

ARNEBIA HISPIDISSIMA (Sieber ex Lehm.) DC.

Protologue Prodr. 10: 94 (1846).

Family Boraginaceae

Vernacular names Arabian primrose (En). Sang de l'homme (Fr).

Origin and geographic distribution *Arnebia hispidissima* occurs from northern tropical Africa, through Egypt, to northern India. In tropical Africa it has been recorded from northern Nigeria, Cameroon, Chad and Sudan.

Uses The roots of *Arnebia hispidissima* are collected from the wild. They are dark purple and provide a dye giving purplish-red to purple colours. In Nigeria the Hausa call the dye 'jinin mutum' (blood of man) and it is used to colour clothes and the body. In India the dye is included in the group of *Boraginaceae* species the roots of which are sold under the commercial name 'ratanjot', used to colour food and to dye silk. In Sudan the plant is grazed by sheep. In Indian traditional medicine root extracts are used to treat ulcers, boils, cuts, throat complaints, heart problems, headache and fever, and extracts of the whole plant as a stimulant, tonic, diuretic and expectorant.

Properties The red pigment in the roots of *Arnebia hispidissima* is composed of a group of naphthoquinonic dyes including shikonin (and esters), its optical isomer alkannin (and derivatives) and their common racemic form shikalkin, as well as arnebifuranone which is another type of compound. The same naphthoquinonic colorants are also present in the roots of several other *Boraginaceae* species traditionally used as body paint or textile dyes in other parts of the world (e.g. *Alkanna tinctoria* (L.) Tausch. in Europe and the Mediterranean region, *Lithospermum erythrorhizon* Siebold & Zucc. in China and Japan, *Lithospermum caro-*

liniense (Walter ex J.F.Gmel.) Macmil. in North America). They are poorly soluble in water but more easily so in alcohol and fats, which explains their uses as colorants in cosmetics. In India, medicinal active principles isolated from the aerial parts include arnebins and the triterpenoids betulin, β-amyrin and lupeol. All compounds (of both roots and aerial parts) showed antimicrobial activity, more powerfully against bacteria than against fungi.

Botany Annual herb up to 40 cm tall, erect or ascending, much branched from the base, with strong red roots, densely covered with white bristles. Leaves alternate, simple, without stipules, sessile; blade linear-lanceolate, 1.5–8 cm × 0.2–1 cm, apex acute to obtuse, margin entire. Inflorescence spike-like, consisting of terminal, short and dense scorpioid cymes, simple or forked; bracts leaf-like. Flowers sessile, bisexual, regular, 5-merous; calyx deeply divided, lobes 5–8 mm long, unequal, hardly accrescent in fruit; corolla tubular, 8–16 mm long, yellow, tube hairy inside, lobes small; stamens inserted at about the middle of the corolla tube, filaments c. 0.5 mm long, anthers 1.5 mm; ovary superior, 4-lobed, style c. 1 cm long, 2-lobed, each lobe ending in a reniform stigma. Fruit consisting of 4 pyramidal nutlets up to 2 mm long, ventrally keeled, granulose to smooth, grey to yellow-brown.

Arnebia comprises about 25 species, and is confined to tropical Africa, the Mediterranean region and the Himalayas. In tropical Africa 3 species occur. In traditional medicine in China, roots of other *Arnebia* species have similar uses to those of *Arnebia hispidissima* in India.

Ecology *Arnebia hispidissima* occurs on dry, stony or sandy soils, often in desert plains and disturbed localities along fields.

Genetic resources and breeding *Arnebia hispidissima* is widespread and not in danger of genetic erosion.

Prospects The dyeing properties of *Arnebia hispidissima*, especially the liposolubility of the root dyes make it an interesting source of colorants for the food and cosmetic industries. Collecting of the roots in their wild environment could quickly lead to the rarefaction and even extinction of the plant, should material in large quantities be needed. Consequently, the possibilities for cultivation should be investigated. The medicinal properties of *Arnebia hispidissima* most probably will remain only locally of importance, although they deserve more research.

Major references Andrews, 1956; Boulos, 2000; Burkill, 1985; Cardon, 2003; Heine, 1963; Singh et al., 2004.

Other references Burkill, 2000; Jain, Singh & Jain, 2000; Jain, Jain & Singh, 2003; Khan, Chandrasekharan & Ghanim, 1983; Shukla et al., 2001.

Authors P.C.M. Jansen

BAPHIA NITIDA Lodd.

Protologue Bot. Cab. 4(7): t. 367 (1820).

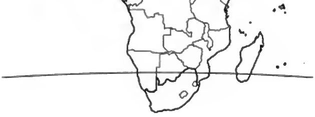
Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Chromosome number $2n = 44$

Vernacular names Camwood (En). Bois de cam, bois rouge (Fr).

Origin and geographic distribution *Baphia nitida* occurs wild from Senegal to Gabon. It is often cultivated near villages, formerly as a dyewood especially in Sierra Leone and Liberia, now more often as an ornamental shade tree or as fence and hedge.

Uses The heartwood (camwood) and roots of *Baphia nitida* yield a red dye that was used locally until recently to dye raffia and cotton textiles. The name 'camwood' is most probably derived from the Sierra Leone Temne or Bulom name 'kam'. It was exported on a large scale to Europe from the 17th century and to North America from the 18th century as one of the main 'redwood' dyes for wool, cotton and silk. Camwood was considered by European and American dyers to have a colouring power 3–4 times stronger than the other 'insoluble' redwoods they were using. In the wool industry, camwood was not only used to obtain red colours but a large range of reddish to dark brown



Baphia nitida – wild

colours called 'drabs', 'muddy brown' and 'London smoke', mostly in combination with other dyewoods. In small quantities, it was an ingredient of recipes for bronze-green colours and was used as ground dye followed by a logwood (*Haematoxylum campechianum* L.) dye bath. It was used for dark grey and black colours in the wool-cloth industry until the beginning of the 20th century. It was a major source of bright to dark red colours in the big European cotton-printing industries, e.g. to dye bandanas in 'mock turkey red', and it was also used, principally in the United Kingdom, to dye silk pink, 'acid brown' and 'light claret'. In West Africa, powdered heartwood is a familiar red body paint and the paste is much used as a cosmetic for the skin, e.g. in Liberia, Côte d'Ivoire and Ghana. As body paint it is considered to have magic powers: Guéré and Krou healers of Côte d'Ivoire use it for religious ceremonies, and in Ghana warriors who had killed an enemy or a leopard painted their foreheads with camwood for ritual dances.

By soaking the dried and ground roots in water a red liquid is obtained, which is used for painting furniture. In southern Benin and south-western Nigeria, Yoruba ceremonial masks are painted dark red with a decoction of the wood.

Baphia nitida wood is used for house posts, rafters, naves of wheels and utensils such as walking sticks, mortars, pestles, tool-handles and farm implements. It was formerly exported to Europe for turnery and cabinetry. The plant is grown as an ornamental for shade, or as hedge and fence. The leaves are used as fodder and in southern Ghana *Baphia nitida* is recommended for propagation in livestock rearing areas because of its good palatability, continuous availability and high protein content. In Nigeria the seeds are eaten by Igbo people and the twigs are used as chewing sticks. In some regions the tree is considered sacred, endowed with the power to protect against evil spirits and to attract benevolent ones. In Nigeria, Tiv people colour the inside of a gourd prepared as a beehive with the red dye to attract a swarm to settle there and Yoruba honey-hunters rub their body with the dye paste to prevent bee-stings.

The leaves or leaf juice are applied against parasitic skin diseases, and a leaf infusion is drunk to cure enteritis and other gastrointestinal problems. In Ghana, Côte d'Ivoire and Nigeria the leaves and bark are considered haemostatic and anti-inflammatory, and are used for healing sores and wounds. In Côte d'Ivoire powdered leaves are taken with palm wine or food to cure venereal diseases, and leaf sap is applied as eye drops against jaundice. An extract of young leaves with some salt and red pepper is used as nose drops against headache. In Nigeria powdered heartwood is made into an ointment with shea butter (obtained from the seeds of *Vitellaria paradoxa* C.F. Gaertn.) which is applied against stiff and swollen joints, sprains and rheumatic complaints. In Sierra Leone a bark decoction is drunk to cure cardial pain and bark and leaves are prepared as an enema to treat constipation. In Nigeria and Ghana the pounded dried root, mixed with water and oil, is applied to a ringworm-like fungus attacking the feet. Finely ground root bark, mixed with honey, is taken against asthma. In Côte d'Ivoire a leaf extract of camwood and *Senna occidentalis* (L.) Link is drunk against asthma. In Benin a decoction of the leaves is taken against jaundice and diabetes; in combination with leaves of *Morinda lucida* Benth. it is a treatment against female sterility and painful menstruation. Externally it is applied, together with *Cissus quadrangularis* L., against bone fractures. A decoction of the bark is drunk against epilepsy.

Production and international trade Up to about the 1950s there was considerable export of camwood particularly from Sierra Leone and Liberia to Europe and the United States, both as dye and for wood turning and cabinet making. The export was mainly in the shape of logs cut into short lengths rather than in the form of powder or extract, allegedly to facilitate quality control.

Properties The dye is found in the heartwood, which often is of small size. It is present in varying concentrations, up to about 23%. The dye is soluble in alkali and alcohol, much less so in water. The principal dyeing substances are the isoflavonoid-flavonoid dimers santalins A and B and santarubins A, B and C, but several other compounds such as baphic acid, baphiin, deoxysantarubin, homopterocarpin, maackiain, pterocarpin and santal possibly also contribute to the colouring properties. In the Colour Index the number of the dye is 75560 and it is classified as Natural Red 22, together with other redwoods.

A red tinge may appear on wounding the bark, and soaking the bark in water also yields a red dye.

In the leaves saponins, flavonoid glycosides and true tannins are present. An ointment made from the leaves showed anti-inflammatory activity in mice and rats and this supported the external use in traditional medicine. Extracts of fresh leaves inhibited digestion in mice and rats, and showed antidiarrhoeal effects. Leaf extracts also demonstrated analgesic activity in mice.

Total dry matter content of leaves and young twigs browsed by cattle in Ghana was about 20%. In Nigeria the nutrient content of leaves per 100 g dry matter was approximately: crude protein 19 g, ether extract 2.5 g, ash 4.3 g, crude fibre 23 g, N-free extract 51 g, acid-detergent fibre 57 g, lignin 13 g, cellulose 29 g, Ca 0.4 g, Mg 0.2 g, K 1 g, P 0.2 g, Fe 23 mg, Cu 20 mg and Zn 5 mg.

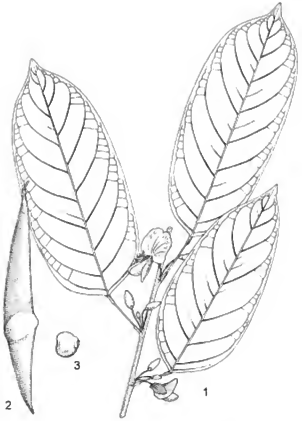
When freshly cut the sapwood is yellowish white, emitting an unpleasant smell, scarcely darkening when dry. The heartwood is pale brown when fresh, turning rapidly to dark red or orange upon exposure. The wood is extremely hard, heavy and durable, close-grained and of fine texture. It carves and turns well and planes smoothly.

Adulterations and substitutes Substitutes for camwood are the dyes obtained from other insoluble redwoods, such as Benin camwood (*Baphia pubescens* Hook.f.) and barwood (*Pterocarpus soyauxii* Taub. and *Pterocarpus erinaceus* Poir.) from Africa, sandalwood (*Pterocarpus santalinus* L.f.) from India and narrawood (*Pterocarpus indicus* Willd.) from Myanmar and the Philippines.

Description Many-stemmed erect shrub or small tree up to 9 m tall with glabrous to densely pubescent branchlets. Leaves alternate, simple and entire; stipules quickly caducous; petiole 1–4 cm long, prominently thickened at base and at top; blade ovate, elliptical, obovate or lanceolate, 5–21 cm × 3–9 cm, base rounded to cuneate, apex acuminate, slightly leathery, almost glabrous, pinnately veined. Flowers in axillary fascicles, 1–5-flowered, bisexual, papilionaceous; pedicel slender, 3–17 mm long; calyx spathaceous, 8–10 mm long, glabrous but with a tuft of brown hairs at apex; corolla with standard suborbicular, 1–2 cm in diameter, white with a yellow centre, wings and keel white with a pocket near the base; stamens 10, filaments unequal, free, up to 7 mm long; ovary superior, sessile, glabrous, sometimes with a row of silvery hairs along the dorsal margin, 1-celled, style curved, filiform, stigma small. Fruit a compressed pod 8–16.5 cm × 1–1.5 cm, pointed at both ends, 1–4-seeded. Seeds almost circular in outline, 1–1.5 cm in diameter, brown.

Other botanical information *Baphia* comprises about 45 species and is largely confined to tropical Africa with most species present in Nigeria and Cameroon. Benin camwood (*Baphia pubescens* Hook.f. (synonym: *Baphia bancoensis* Aubrév.)) has a distribution similar to that of *Baphia nitida*, but extending into DR Congo and their vernacular names and uses are more or less interchangeable. Its heartwood is also a source of a red dye but it has been less exploited. *Baphia pubescens* differs from *Baphia nitida* in its leaves, which are hairy below, and in its hairy ovary.

In northern Namibia the roots of *Baphia massaiensis* Taub. subsp. *obovata* (Schinz) Brummitt are used as a source of a red dye for leather hides. The roots are crushed, mixed with water, and skins are steeped in the dye bath, taking up the red dye within about one day. Formerly ox-stomachs used as aprons by women were dyed in the same way, then tanned and stretched out to dry. *Baphia massaiensis* occurs from southern DR Congo and Tanzania to northern South Africa, and differs from *Baphia nitida* in its long bracteoles, pubescent ovary and usually rounded or obtuse leaf apex. It is an extremely variable species.



Baphia nitida – *1, part of flowering branch; 2, fruit; 3, seed.*
Redrawn and adapted by Achmad Satiri Nurhaman

Ecology *Baphia nitida* often grows as an understorey tree in wetter parts of coastal regions, in rainforest, in secondary forest and on abandoned farmland, from sea-level up to 600 m altitude.

Propagation and planting Camwood is easy to cultivate and can be propagated by seeds and cuttings. For best results cuttings should be taken from rather young parts.

Handling after harvest For dyeing purposes, the sapwood is removed from the trunk and the heartwood is sawn or cut into parts 30–50 cm long and dried. When dry it is ready for transport. To extract the dye the wood is cut into much smaller pieces or pulverized. Because the dye does not dissolve well in water the wood is boiled for 1.5–2 hours in a 45% alcohol solution or in a sodium carbonate solution (30 g for every 100 g wood). The resulting solution is diluted with water until the desired dye bath concentration is obtained, which differs according to the fibre or type of textile to be dyed and the colour wanted. Using different mordants, applied before and after the dye bath, and various mixtures with other dyewoods, a wide range of colours from red to brown, green, grey, purplish and black can be obtained.

Genetic resources *Baphia nitida* is widespread and not in danger of genetic erosion.

Prospects *Baphia nitida* is a multipurpose tree: the wood is a source of fast red colorants and an interesting timber, its young foliage is a source of fodder and both wood and foliage are used in traditional medicine. The timber and fodder uses seem most important at present, but increasing interest in natural dyes might revive the value of camwood to the level it had in the past. Extraction of the colorants in the countries where the trees grow, to produce liquid or powdered extracts, would bring much added value and allow further use of the extracted wood as fuel.

Major references Burkill, 1995; Cardon, 2003; Irvine, 1961; Onwukaeme, 1995; Onwukaeme & Lot, 1992; Soladoye, 1985; Ubani & Tewe, 2001.

Other references Adjanohoun & Aké Assi, 1979; Adjanohoun et al., 1989; Barnes, 1998; Mathieson et al., 1973; Onwukaeme & Lot, 1991; Rodin, 1985; Surowiec, Nowik & Trajanowicz, 2004; Ubani, Tewe & Moody, 2000.

Sources of illustration Soladoye, 1985.

Authors D. Cardon & P.C.M. Jansen

BARRINGTONIA RACEMOSA (L.) Spreng.

Protologue Syst. veg. 3: 127 (1826).

Family Lecythidaceae

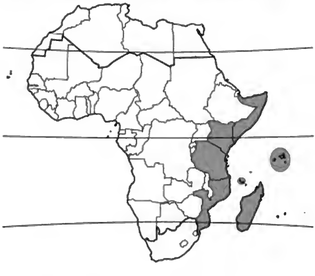
Chromosome number $2n = 52$

Vernacular names Barringtonia, brack-water mangrove, freshwater mangrove, fish-poison tree, powder-puff tree (En). Barringtonia, bonnet d'évêque, manondro (Fr). Massinhana (Po). Mtomondo (Sw).

Origin and geographic distribution *Barringtonia racemosa* is found in the coastal areas of eastern Africa from Somalia to South Africa, through Madagascar and other Indian Ocean islands to tropical Asia, Micronesia, Polynesia and northern Australia.

Uses The bark of stems and roots of *Barringtonia racemosa* has a high tannin content and is used locally for tanning. Uses as a dye have not been recorded, but the type of tannins present in the bark is widely used all over the world for dyeing vegetable fibres into shades of reddish brown and also grey and black with iron mordants.

The bark is used as a source of fibre, e.g. to make tying material. The powdered bark and all other parts of the plant have been widely used as a fish poison and extracts have proved effective as an insecticide, e.g. against citrus aphids. Young leaves, after soaking in lime water to remove their bitterness, are eaten as a vegetable and the pounded seeds produce an edible flour. The wood provides suitable firewood, but it has also been used for veneer, plywood, light and temporary construction, and pulp for the paper industry. Extracts or preparations of the fruit are used against malaria, cough, asthma, jaundice, headache, eye in-



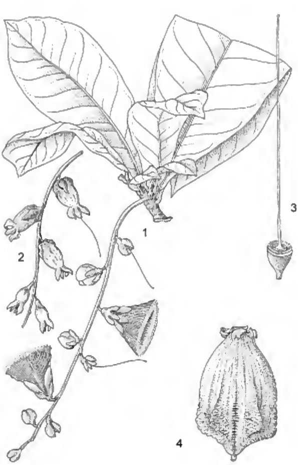
Barringtonia racemosa – *wild*

flammation, diarrhoea and sores, and a bark decoction is applied externally to treat rheumatism. In eastern Africa a root decoction is used as a febrifuge. In Malaysia the leaves are used to treat high blood pressure and as a depurative. *Barringtonia racemosa* is a decorative ornamental tree growing rapidly and easily.

Production and international trade The bark and wood of *Barringtonia racemosa* are only used locally without any international trade. In local trade, however, wood is sold in mixed consignments of light or medium hardwood, although the proportion of *Barringtonia racemosa* is probably minor. 'Putat' is the South-East Asian standard trade name for timber of *Barringtonia* and *Planchonia* species.

Properties Data on tannin content and tanning characteristics are very scarce, but total tannin content of the bark has been estimated at 18%. The tannins belong to the group of condensed proanthocyanidins giving a reddish leather. From this type of tannins phlobatannins are formed in slightly basic solutions; these are good sources of reddish brown dyes. The yield of purified saponins from the dried ripe fruit is about 13% and of sapogenin 4%. In the roots of *Barringtonia racemosa* triterpenes such as barrigenols and neo-clerodane diterpenoids (nasimaluns A, B) are also present. Ethanol extracts of the leaves displayed cytotoxicity against human cervical carcinoma cell lines at a CD_{50} value of 10–30 µg/ml. Intraperitoneal daily administration of methanolic seed extracts in mice showed cytotoxic effect against Dalton's lymphoma ascitic cells, without toxicity up to a dose of 12 mg/kg; oral administration showed only marginal activity. Aqueous bark extracts showed antinociceptive effects in rats, without producing side effects or toxicity.

Description Small to medium-sized tree up to 20(–27) m tall; bole up to 50 cm in diameter, sometimes with buttresses; bark smooth or fissured, grey or yellow; knee roots (pneumatophores) sometimes present. Leaves alternate, crowded towards the ends of twigs, simple; stipules very small, caducous; petiole up to 1.5 cm long, slightly winged; blade elliptical to obovate-oblong or oblanceolate, 5–42 cm × 2–16 cm, base cuneate, apex acuminate, margin entire to toothed. Inflorescence an axillary, pendulous raceme up to 70(–100) cm long. Flowers bisexual, almost regular; pedicel up to 1.5(–2.5) cm long; calyx tubular, splitting into (2–)3–4(–5) lobes up to 1.5 cm long, green, flushed pink or purple; petals 4, elliptical, 1–3 cm × 0.5–1.5 cm, adnate to staminal tube, white, often tinged pink outside; stamens numerous, connate into a short tube at base, in several whorls, 2–5 cm long, white to pink, inner whorl without anthers; ovary inferior, globular, (2–)3–4(–6)-celled, style simple, slender, 2–6 cm long, stigma small, head-shaped. Fruit an ovoid-tetragonous drupe 3–9 cm × 2–5.5 cm, tapering at base, truncate at apex, indehiscent, green, often tinged purple or red, usually 1-seeded. Seed ovoid-tetragonous, 2–4 cm × 1–2.5 cm. Seedling with hypogeal germination; hypocotyl remaining within fruit wall and seed coat, massive; cotyledons absent or rudimentary; shoot with several scales at base.



Barringtonia racemosa – 1, flowering twig; 2, young infructescence; 3, ovary and style; 4, fruit.
Source: PROSEA

Other botanical information *Barringtonia* comprises about 40 species. South-East Asia is the centre of diversity with 32 species. Two species are indigenous to eastern Africa and the Indian Ocean islands. *Barringtonia asiatica* (L.) Kurz (distributed from eastern Africa, through tropical Asia to Australia and the Pacific) has erect stout terminal inflorescences and broadly pyramidal fruits up to 12 cm long and wide. It is used as a timber tree and in traditional medicine.

Growth and development Branching in *Barringtonia racemosa* is predominantly sympodial. Flowering is throughout the year and takes place during the night with the corolla opening early in the evening and falling the next morning. About half of the flowers in a single inflorescence bloom simultaneously. Pollination of the fragrant flowers is generally by bats or insects (mainly moths) which are also attracted by the copious nectar. After shedding of the flowers, the inflorescences are often crowded with ants attracted by the nectar. Fruits are buoyant thanks to a thick layer of spongy, fibrous tissue, and are dispersed by water currents. Seed dispersal is usually by animals that feed on the fruits.

Ecology *Barringtonia racemosa* is found in primary and secondary forest, mostly restricted to inundated flood plains on tidal river banks, or in swampy localities, sometimes behind the mangrove or in the upper mangrove swamp. Along tidal rivers or in upper mangrove swamps it may form almost pure stands. It grows well under slightly saline conditions or on beaches near the high water level, with a preference for heavy clay, loam or rich volcanic soils, occasionally up to 500(–900) m altitude.

Propagation and planting *Barringtonia racemosa* can be propagated by seed and cuttings.

Harvesting The bark can be harvested whenever needed. It is usually collected from the wild, and should be collected very carefully in order not to kill the trees (parts on the stem should be left undisturbed). Harvested trees should be given enough time to regenerate new bark.

Handling after harvest The bark is pulverized before the tannin is extracted. The most simple extraction method is by leaching several times with soft, clean, hot (not boiling) water, taking care that the bark is completely covered with water to prevent oxidation. By repeating the leaching process several times with new bark material, the tannin concentration of the liquid increases.

Genetic resources As trees of *Barringtonia racemosa* are not commercially harvested for tannin or timber in Africa, there is little threat to its genetic diversity. There are no records of *Barringtonia* in seed or germplasm banks.

Prospects As a source of tannin *Barringtonia racemosa* will remain only very locally important. The bark could also serve as a source of fast brown and black dyes for vegetable fibres. In view of the poor wood quality it is unlikely that its importance for timber, either by exploiting natural forest or by establishing plantations, will increase. Its medicinal, insecticidal and nutritional properties need better investigation.

Major references Burkill, 1935; Coates Palgrave, 1983; Fernandes, 1978a; Lim, 1998; Mesfin Tadesse & Edwards, 1995; Perrier de la Bâthie, 1954; Sangai, 1971; Thulin & Moggi, 1993; Yaplito, 2001.

Other references Beentje, 1994; Decary, 1946; Deraniyagala, Ratnasooriya & Goonasekara, 2003; FAO, 1984; Hasan et al., 2000; Kokwaro, 1993; Palmer & Pitman, 1972–1974; Payens, 1967; Thomas et al., 2002; Watt & Breyer-Brandwijk, 1962; Williams, 1949.

Sources of illustration Lim, 1998.

Authors R.N. Kaume

BERTIERA SPICATA (Gaertn.f.) K.Schum.

Protologue Bot. Jahrb. 23: 451 (1897).

Family Rubiaceae

Chromosome number $2n = 22$

Origin and geographic distribution *Bertiera spicata* occurs from Senegal to western Côte d'Ivoire.

Uses The bark of *Bertiera spicata* yields a yellow dye, which is used in West Africa to dye cotton.

Botany Shrub up to 5 m tall; twigs clothed with long spreading hairs. Leaves opposite, simple and entire; stipules triangular, c. 3 cm long, caducous; petiole up to 1.5 cm long; blade ovate-oblong, 15–25 cm × 4–7 cm, base rounded to cuneate, apex acuminate, hairy below, especially on the 10–12 pairs of lateral veins. Inflorescence a lax false spike up to 20 cm long. Flowers bisexual, regular, 5-merous, almost sessile, c. 1 cm long, white, yellow-green or pinkish; calyx tubular with small triangular lobes, pubescent; corolla tubular with ovate lobes, hairy inside; stamens inserted at corolla throat, almost sessile; ovary inferior, 2-celled, style filiform-clavate, with 2 compressed oblong branches. Fruit a soft and juicy, globose berry c. 5 mm in diameter, marked with shallow longitudinal furrows when young, brown, many-seeded.

Bertiera comprises 40–50 species, with about 30 in tropical Africa, 5 in the Indian Ocean islands and 5 in tropical America. It belongs to the tribe *Gardenieae*. *Bertiera spicata* belongs to subgenus *Bertiera*.

Ecology *Bertiera spicata* occurs in the understorey of swamp, gallery and mangrove forests, often near the coast, sometimes also in secondary vegetation and along roadsides.

Genetic resources and breeding *Bertiera spicata* is rather widespread in a range of habitats, and does not seem to be in danger of genetic erosion.

Prospects At the best *Bertiera spicata* will remain a source of yellow dye of minor local importance.

Major references Burkill, 1997; Hepper & Keay, 1963; Holmgren et al., 2004; Robbrecht, Rohrhofer & Puff, 1993.

Authors P.C.M. Jansen

BIXA ORELLANA L.

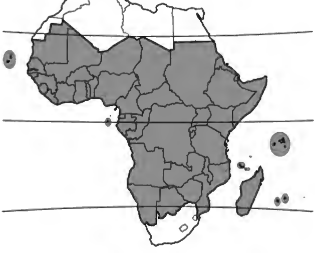
Protologue Sp. pl. 1: 512 (1753).

Family Bixaceae

Chromosome number $2n = 16$

Vernacular names Annatto, lipstick tree (En). Rocouyer, rocou, roucou (Fr). Anato, urucuzeiro, urucu, açafrão do Brasil (Po). Mzingifuri (Sw).

Origin and geographic distribution *Bixa orellana* is native to tropical America, where since antiquity the red dye extracted from its seeds has been endowed with symbolic power (representing eternal life, sun, fire and blood, majesty and power) and used to colour and flavour food. *Bixa orellana* became popular worldwide and at present it is planted and naturalized almost pantropically. In tropical Africa it is cultivated on a commercial scale in Kenya and on a small scale in all countries. It has become naturalized very locally, e.g. in Kenya and Tanzania.



Bixa orellana – planted

Uses The main product obtained from *Bixa orellana* is an organic dye present in the seed coat, commercially called 'annatto' in English, 'rocou' in French, 'achiote' in Spanish and 'orlean' in German. Due to its solubility in lipids, it is widely used in the food industry for giving red to orange-yellow colours to cheese, butter, oils, margarine, ice-cream, candy, bakery products and rice. It owes its success in the dairy sector to the comparative instability of equivalent certified synthetic materials as well as to its proven non-toxicity and vitamin A content. In Latin American cuisine, annatto is not only used to give an attractive red colour to meat, fish and rice dishes but also to impart distinctive flavour notes. It is used in the cosmetic industry in the production of nail gloss, hair oil, lipstick, soap and in household products like floor wax, furniture polish, shoe polish, brass lacquer and wood stain. The dye, mixed with oil, is used to decorate the body, for instance in West Africa, Guyana and New Guinea, and when used in this way it is believed also to repel insects and to protect against sunburn. Annatto has been used for dyeing cotton, wool and particularly silk, giving an orange-red colour which becomes more yellow if the dye is mixed in the dye-bath with wood-ash or sodium carbonate and if the dyed fabric is passed through a weak solution of tartaric or citric acid. For colouring textiles, annatto has largely been replaced by synthetic dyes because it is not a fast dye. Exposure to light soon causes fading. However, the dye is somewhat resistant to soap, alkalis and acids. Wood, bamboo, rattan and wickerwork can be dyed with it. In West Africa, the Baoulé people of Côte d'Ivoire use a paste of crushed seeds, lemon juice and water as paint for door posts, wooden masks and toys. Sometimes annatto is used in mixtures with other vegetable dyes such as curcumin from turmeric (*Curcuma longa* L.).

The presscake of the seed and fruit is used as fodder. Fibres extracted from the bark are used for cordage. The wood from the aged tree makes good firewood. *Bixa orellana* is often planted as an ornamental in homegardens and public parks, valued for its beautiful white and pink flowers and red fruits. It is also planted as a hedge. The seeds and leaves are used in traditional medicine. The seeds are edible and nutritive but slightly purgative and said to be effective against fever, dysentery, kidney diseases and poisoning by cassava. In DR Congo a paste of fruits and seeds is applied against itch. In Gabon a leaf decoction is taken to stop vomiting, in DR Congo as a gargle for sore throat and tonsillitis, in the Seychelles and Mauritius as a bath against muscular pain. In Ethiopia the leaves are applied as a wound dressing and in Mauritius against headache. In Mexico and Paraguay seeds and sap have been used against mouth diseases.

Production and international trade The main commercial producers of *Bixa orellana* are countries in South America, Central America, the Caribbean, Africa, and also India and Sri Lanka. Peru is the largest exporter of annatto seed, annually about 4000 t, Brazil the largest producer with about 5000 t. Kenya exports annually about 1500 t annatto seed and extracts and after Peru is the largest exporter, particularly to Japan. Côte d'Ivoire and Angola are also exporters. In Kenya *Bixa orellana* is grown by smallholders, particularly near the coast in Kilifi District, Kwale escarpment and Shimba hills area. In many tropical American countries the dye is collected both from plants cultivated in homegardens and from plants growing in the wild. Production statistics are not usually available, and would not provide a reliable guide to international trade since many of the producing countries utilize significant quantities domestically (e.g. Brazil is a large producer and consumer, needing additional imports). Annual world production of dried annatto seed at the beginning of the 21st century is estimated at about 10,000 t of which 7000 t enters international trade. The average market price per t seed varies strongly; between 1984 and 1990 it fluctuated between US$ 600 and US$ 2300. The main market for annatto is the United States with 3000 t/year, followed by western Europe (2500 t) and Japan (1500 t). Some 70% of the product is used in the importing countries to colour cheese. Trade in annatto extracts (instead of dried seeds) has increased strongly since the 1980s, with the water soluble norbixin extract being largest in volume, followed by vegetable oil extracts, and solvent-extracted bixin in third place.

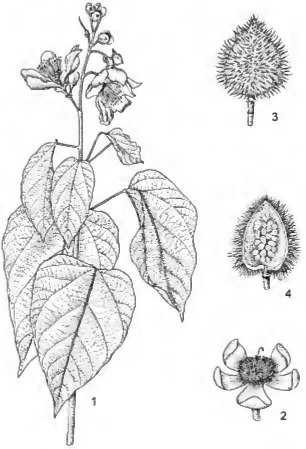
Properties The colouring matter present in the seedcoat of *Bixa orellana* is annatto, known in the European Union as E160(b). Other codes used for annatto are CI 75120 and Natural Orange 4. In the European Union the use of annatto is permitted in a variety of food products; in the United States it has FDA GRAS (Generally Recognized As Safe) status for use in food, drugs and cosmetics. The principal components of annatto are the carotenoids bixin and norbixin. Bixin, the monomethyl ester of a dicarboxylic carotenoid ($C_{25}H_{30}O_4$), is the naturally occurring form, norbixin ($C_{24}H_{26}O_4$) is the saponified form of the same carotenoid. They are chemically related to lycopene and saffron. Bixin and norbixin normally occur in the cis form, but small amounts of the more stable trans forms are formed on heating. The cis forms are redder than the trans forms and thus are the pigments used commercially. The carboxylic acid portions of the norbixin molecule contribute to its solubility in water, while the ester component of bixin makes it more soluble in oil. As the ratio bixin : norbixin in annatto can vary this provides flexibility for its use in a wide variety of applications and a range of colours from orange to red. Norbixin provides the golden-yellow colour of cheddar cheese and is also preferred in cheese production because it associates with the curd rather than the whey. Annatto also contains small quantities of other carotenoids and degradation products of bixin. A yellow degradation product, termed C_{17} yellow pigment, is produced on heating. The ethyl ester of bixin, named ethyl bixin ($C_{27}H_{34}O_4$), is used as a suspension in vegetable oil for colouring foods. It imparts a golden-yellow colour. Bixin itself has no provitamin A activity, but other fractions of the dye do have it, which adds to its usefulness in colouring margarine and butter. Three methods of extraction from the seed are in general use, which yield 3 products each with its own characteristics. Annatto can be prepared by extraction with an edible vegetable oil yielding a solution of mainly bixin in the oil. Extraction with an aqueous solution yields annatto rich in norbixin. Finally, extraction with solvents followed by removal of the solvent yields mixtures of bixin and norbixin crystals or powder. For numerous special applications special formulations are made.

The bixin content of the seed varies strongly, usually 2–4%. The proportion of bixin present in commercial annatto extracts varies considerably, and depends on the nature of the product. A solution in vegetable oil usually contains 0.2–5% bixin. Norbixin concentrations of commercially available spray-dried annatto powder range from 7.5% to 15%.

The seeds have a high nutritive value, containing a small amount of fatty oil (5%) and about 13% of protein. The seedcoat contains a wax-like substance which acts as a vermifuge and the flowery scent of the seed is caused by the tetracyclic sesquiterpene ishwarane. The fruit wall contains tannin. Ellagic acid and cyanidin have been isolated from the leaves. Extracts of the fruit and the leaf showed antibacterial activity against *Staphylococcus aureus*, *Escherichia coli* and *Salmonella typhi*. A gum extracted from the bark is similar to gum arabic. The wood is soft, light (air-dry weight about 400 kg/m^3), yellowish to pinkish yellow and not durable.

Adulterations and substitutes The main competitor for annatto extracts in certain food applications is synthetic β-carotene.

Description Evergreen shrub or small tree up to 6(–8) m tall; trunk up to 10 cm in diameter; bark pale to dark brown, tough and smooth, sometimes fissured, lenticellate, inner bark with orange sap; branches greenish and densely rusty-scaly when young, later becoming dark brown, ringed at nodes. Leaves arranged spirally, simple and entire; stipules quickly caducous, leaving horseshoe-shaped scars; petiole terete, thickened at both ends, 1–13 cm long; blade ovate, 5–25 cm × 3.6–16 cm, shallowly cordate to truncate at base, long-acuminate at apex, dark green above, greyish or brownish-green beneath, scaly when young but glabrescent, 5-veined from the base. Inflorescence a terminal, 8–50-flowered panicle or corymb. Flowers bisexual, regular, fragrant; pedicel 0.5–1 cm long, scaly, thickened at the apex bearing 5–6 large glands; sepals 4–5, free, obovate, 10–12 mm long, caducous; petals (4–)5–7, free, obovate, 1.5–3 cm × 1–2 cm, pinkish, whitish or purplish tinged; stamens numerous, free, anthers violet; ovary superior, 1-celled, style 12–15 mm long, thickened upwards. Fruit a globose or broadly to elongated ovoid capsule 2–4.5 cm × 2–4 cm, more or less densely clothed with long bristles, green, greenish brown or red when mature, 2-valved, many-seeded. Seeds obovoid and angular, 4–5 mm long, with bright orange-red fleshy seedcoat and small whitish aril around the top of the long funicle. Seedling with epigeal germination, cotyledons thin, ovate, veined, hypocotyl fairly long.



Bixa orellana – 1, flowering branch; 2, flower; 3, fruit; 4, halved fruit showing seeds.
Source: PROSEA

Other botanical information *Bixa* is the only genus of the family *Bixaceae* and comprises about 5 species confined to Central and South America, with only *Bixa orellana* cultivated and sometimes naturalized in many other tropical regions of the world. The variation in shape and colour of the fruits of *Bixa orellana* is considerable. The shape varies from globose to ovoid, broad-topped and shortly acuminate to elongate-ovoid and long-acuminate. The colour varies from white to green and red. The types with ovoid, broad-topped and shortly acuminate fruits are reported to have a lower bixin content than the ones with globose or elongated fruits, and are consequently considered inferior. Types with white flowers occur, but pink-flowered plants are much more common. Although many cultivated types exist, there is no official cultivar classification.

Growth and development Mature seeds taken directly from fresh fruits germinate readily in 7–10 days under moist conditions. Cleaned, sun-dried seeds retain viability for over one year, but their germination rate falls to 12% in 3 years. Seed-grown plants take comparatively long to flower and initially do so sparingly; they are very tall and exhibit much variation. Plants propagated by cuttings flower early and profusely and bear fruit within two years. Pollination is by insects; honeybees are observed in plenty around the plant. Fruits mature 5–6 months after pollination. Production of seed reaches a maximum in 4–12-year-old plants, which can remain productive for more than 20 years.

Ecology *Bixa orellana* requires a frost-free, warm, humid climate and a sunny location. Optimum conditions are an average temperature of 20–26°C in areas with an average annual rainfall of 1250–2000 mm, well distributed over the year but with a dry season for seed ripening. However, *Bixa orellana* can grow in a wide variety of tropical to subtropical climates and needs little care, though in regions where rainfall is not distributed evenly throughout the year, irrigation may be necessary. It grows on almost any type of soil, with a preference for neutral to slightly alkaline soils. It grows into a larger tree when planted in deeper and more fertile soil, rich in organic matter. It does well on limestone, where the topsoil is only a few cm thick and overlies a coral base. In Africa it is grown from sea-level up to about 2000 m altitude.

Propagation and planting *Bixa orellana* can be propagated by seed and stem cuttings. Seed is sown directly in the field, 2–5 seeds per hole in well-prepared soil, usually at the beginning of the rainy season. After germination only one seedling per hole is retained. Seedlings may be raised in planting trays; they are transferred to 1 kg bags containing a soil mixture and kept in the nursery for 3–4 months before they are transplanted into the field. Hardwood cuttings of 8 mm or more in diameter readily root when a root hormone suitable for hardwood cuttings is applied. Roots are produced in abundance in 7–9 weeks. Rooted cuttings are first transferred into pots or bags and kept in a nursery and can be transplanted to the field after 3 months. For commercial production *Bixa orellana* is planted in rows 3–4 m apart, with plants spaced at 2–3 m within the row, depending on soil and climate.

In vitro production of active compounds Attempts have been made to produce bixin artificially by introducing the 3 genes of *Bixa orellana* that govern bixin synthesis in the plant into a strain of the bacterium *Escherichia coli*, which had been engineered to produce lycopene. This induced the bacterium to convert lycopene into bixin. Tests were promising and the average production level of bixin in *Escherichia coli* was 5 mg per g dry weight. It might be possible to use the 3 genes in sink organs such as tomato fruits, where massive amounts of lycopene are accumulated, to create a competitive alternative source for natural bixin production.

Management Weeding is necessary only in the initial stages of plant growth. Once the canopy is formed, periodic slashing of the weed cover and light pruning to remove dead and weak stems and to balance the shape of the plant are required to increase yield. Lower branches are either trained or pruned to ease management operations. Apical pruning is done to encourage branching and to reduce plant height for ease of harvest. Suckers arising from the roots need to be removed. Earthing up the plants after application of fertilizer will help rejuvenation as a ratoon crop. No artificial pollination is required, but if bees are kept near the plantation, seed yield may increase. *Bixa orellana* grows easily and is tolerant of nutrient-poor soil, rarely showing deficiency symptoms. Chemical fertilizers are not usually applied. Trash is usually collected and burnt outside the field and the ash is added to the field along with poultry or farmyard manure. However, application of NPK fertilizer enriched with boron and molybdenum encourages faster early growth and higher yield.

Diseases and pests *Bixa orellana* is sometimes infested by powdery mildew caused by *Oidium bixae* and *Oidium heveae* which attack mainly young fruits; the latter fungus causes powdery mildew in rubber. A foliar disease of minor importance, caused by the fungus *Phyllosticta bixina*, has been recorded in Guam. Insect pests are of minor importance; they include spiralling whitefly (*Aleurodicus dispersus*), pink wax scale (*Ceroplastes rubens*), transparent scale or coconut scale (*Aspidiotus destructor*), Seychelles scale (*Icerya seychellarum*), and redbanded thrips (*Selenothrips rubrocinctus*). In Indonesia *Bixa orellana* is reported liable to attack by tropical mirid bugs of the genus *Helopeltis* which are destructive in tea plantations.

Harvesting Under favourable conditions the first harvest of *Bixa orellana* can be done 1.5 year after field planting. The fruits should be harvested after they start to turn brown and before they split open. They are dried in the shade and threshed by gently beating with a stick. The seeds can then be collected, dried again, cleaned to remove dust and other plant parts, and stored. Fruits harvested when not yet ripe or when allowed to stay on the plant long after maturity reduce the quality of the product.

Yield No reliable statistics on yield are available. Seed yield is reported to be as high as 3–5 t/ha, but in Sri Lanka yields of only 625 kg/ha have been reported. Usually annual seed yields are 800–1200 kg/ha (0.5–4 kg per tree).

From 1 kg of seed 20–50 g of dye can be obtained.

Handling after harvest Seeds of *Bixa orellana* that have been properly harvested, threshed, and dried to 4–6% moisture content retain their quality for a long time provided they are stored in a cool, dark and dry place. Sun drying takes about 3–10 days. Artificial drying is also done at maximum temperatures of 55–60°C. To avoid deterioration of the pigment content however, storage periods should be kept as short as possible. Clean double jute bags, containing 50–70 kg seeds, are used for export. Ocean shipment is preferably done in ventilated containers.

Traditionally the dye is extracted from seeds by soaking and squeezing in water to dissolve the fleshy seedcoat which contains the dye. The dye is only partially soluble in water and produces a turbid solution. The solution of bixin is concentrated by heating and subsequently cooled to form red crystals. The solution may also be allowed to ferment for about a week, and the dye that has settled at the bottom of the vessel is then separated and dried into cakes. A third traditional method of extracting the dye is to boil the seeds with a sodium carbonate solution, filter, and acidify the filtrate, after which the dye is coagulated by boiling with salt, filter-pressed, washed and dried.

For dyeing cotton, annatto is dissolved in boiling water and a solution of sodium carbonate. The cloth is left in this solution for about 20 minutes, then squeezed dry and washed in acidulated water or an alum solution and dried in the shade. For dyeing silk, a solution is made of equal proportions (by volume) of annatto and sodium carbonate in water; soap is usually added and the dyeing is continued at 50°C for about an hour (longer duration gives a darker colour). Wool is dyed at about 90°C in a water solution of annatto, without addition of other compounds. For 100 g of wool 100 g of annatto is needed.

Genetic resources In its area of natural distribution, *Bixa orellana* is widespread and does not seem to be in danger of genetic erosion. Germplasm collections are available in tropical America, e.g. at CATIE, Turrialba, Costa Rica (about 130 accessions), Universidad Nacional de Colombia, Palmira, Colombia (100 accessions) and CENARGEN, Brasilia, Brazil (22 accessions).

Breeding Selection and breeding in *Bixa orellana* is directed towards improvement of planting stock by breeding high-yielding cultivars adapted to country and climate, but little work has been done so far.

Prospects Many natural dyes have been superseded by synthetic dyes. However, there is still a strong demand for annatto in the food and cosmetic industries because of the carcinogenic activity of many synthetic dyes. Although β-carotene with its vitamin A activity competes with annatto to some extent in household margarine, the lower price and the lesser complexity associated with its use favour annatto. The major use of annatto is in the cheese-making industry, and its prospects are dependent on the growth of this industry. Existing exporters of annatto appear to be capable of servicing any conceivable level of demand for the foreseeable future, and opportunities for new suppliers seem to be limited but not impossible provided a consistent high quality is produced. It is expected that international trade will increasingly shift from seed to seed extracts. The scope for rapid improvement in *Bixa orellana* is still considerable.

Major references Baer, 1976; Burkill, 1985; Donkin, 1974; Green, 1995; Rajendran, 1991.

Other references Adjanohoun et al., 1983a; Anand, 1983; Bouvier, Dogbo & Camara, 2003; Bridson, 1975; Cardon, 2003; Decary, 1946; Francis, 1999; Galino-Cuspinera, Lubran & Rankin, 2002; Gurib-Fakim, Guého & Bissoondoyal, 1995; Jansen, 1981; Miège, 1992; Preston & Rickard, 1980; Raponda-Walker & Sillans, 1961; Wild, 1960; Williamson, 1955.

Sources of illustration Rajendran, 1991.

Authors P.C.M. Jansen

Based on PROSEA 3: Dye and tannin-producing plants.

BRUGUIERA GYMNORHIZA (L.) Savigny

Protologue Lam., Encycl. 4: 696 (1798).

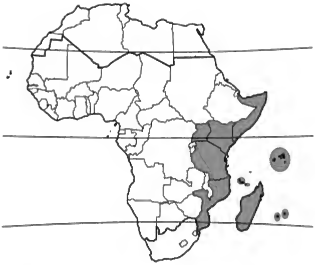
Family Rhizophoraceae

Chromosome number $2n = 36$

Vernacular names Black mangrove, Burma mangrove (En). Palétuvier noir, manglier noir (Fr). Mangue encarnado, pau salgado macho (Po). Mshinzi, muia, mkoko wimbi (Sw).

Origin and geographic distribution *Bruguiera gymnorhiza* occurs along the coasts of tropical eastern and southern Africa, Madagascar and other Indian Ocean islands, through tropical Asia to north-eastern Australia, Micronesia and Polynesia. The tropical Asian area probably represents the centre of origin.

Uses The bark of *Bruguiera gymnorhiza* is



Bruguiera gymnorhiza – wild

rich in tannin and suitable for tanning leather and for treating sails and fishing nets for longer preservation. The bark provides orange to reddish brown dyes without mordanting, and purplish brown, grey and black colours if the fibres or textiles are treated with iron-rich mud or iron salts.

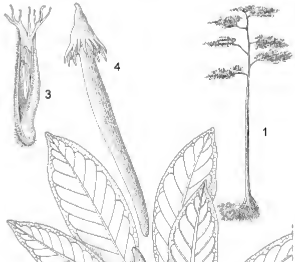
Planks up to 7 m long can be obtained from the bole, and these are used for piles, house posts, rafters, fishing stakes, and electricity or telephone poles. The wood is more commonly used for firewood and charcoal. It can also be used for the paper industry, but the paper is of poor quality. The bark is used as a condiment (e.g. with fish), adhesive and as an astringent medicine against diarrhoea and sometimes malaria. The fruits are sometimes used as an eye medicine. In Mauritius a decoction of the root, mixed with leaves of *Piper pyrifolium* Vahl, is drunk against bleeding, diabetes and hypertension. The leaves and peeled hypocotyls, soaked in water and boiled, can be eaten as a vegetable in times of scarcity. Occasionally *Bruguiera gymnorhiza* is planted to prevent or combat erosion along coasts.

Production and international trade The main countries producing tannin from *Bruguiera gymnorhiza* are East African countries, Indonesia (Kalimantan), Papua New Guinea and the Philippines. At present Borneo accounts for an important proportion of world supplies. However, no figures are available because bark and tannin from *Bruguiera gymnorhiza* are sold together with bark and tannin from other mangrove trees such as *Rhizophora* and *Ceriops* species, collectively called 'mangrove cutch'. In many countries the production of tan bark is only of secondary importance behind the exploitation for charcoal, fuel and timber. Bakau is an international trade name for the timber of *Bruguiera*, *Ceriops* and *Rhizophora*. In eastern Africa, the largest mangrove timber poles usually originate from *Bruguiera gymnorhiza* and are called 'nguso' or 'vigingi' in Swahili.

Properties The percentage of tannin in the bark can vary from 20–43% on dry weight basis, depending on age, season and habitat. The bark of the trunk of large, aged trees is richest in tannin. The tannins belong to the group of condensed tannins of the proanthocyanidin type, which can rearrange in mild alkaline conditions to produce reddish dyes, the phlobatannins. Ellagic acid and di- and tri-O-methylellagic acid have also been identified in the bark. The tanning stuff imparts a reddish colour to leather, and is often mixed with other less colouring tannins in the tanning industry. It is suitable for tanning heavy hides into sole leather. Other parts of the tree also contain tannins (e.g. about 13% in the leaves). The bark contains about 11% mucilaginous sap, which is mainly composed of arabinose, rhamnose and galactose, and also 0.05% of a mixture of bruguierol and isobruguierol (ratio of 5 : 1).

The heartwood is red-brown and distinctly demarcated from the pale brown sapwood. The wood is heavy with a density of about 975 kg/m^3 at 15% moisture content. The grain is usually interlocked, texture fine and even. At 15% moisture content the modulus of rupture is 123.5 N/mm^2, compression parallel to grain 68 N/mm^2, shear 13.5–16 N/mm^2, cleavage 45 N/mm radial and 63.5 N/mm tangential, Janka side hardness 10,300 N and Janka end hardness 7960 N. The rates of shrinkage are moderate, from green to 12% moisture content 2.5% radial and 5.5% tangential. Logs shrink and check excessively during seasoning. The wood is strong and hard. It works and finishes well. It is moderately durable when exposed to the weather or in contact with the ground; poles may have a service life of 10 years. The wood is easy to treat with preservatives and absorbs 200 kg/m^3. The energy value of the wood is 18,950–20,200 kJ/kg.

Description Medium-sized, evergreen tree up to 36 m tall; bole up to 65 cm in diameter, buttressed; bark grey to almost black, roughly fissured, usually with large corky lenticels on buttresses and base of stem; knee roots or pneumatophores present. Leaves decussately opposite, simple, and entire; stipules c. 4 cm



Bruguiera gymnorhiza – 1, tree habit; 2, flowering branch; 3, petal with enclosed stamen-pair; 4, fruit and hypocotyl.
Source: PROSEA

long, often reddish; petiole 2–4.5 cm long, often reddish; blade elliptical to oblong, 8–22 cm × 5–9 cm, base cuneate, apex acute, leathery, glabrous, pinnately veined. Flowers solitary, 3–3.5 cm long, generally nodding; pedicel 1–2.5 cm long, bright red on the outside curve; calyx tubular for 1–2 cm, 10–16-lobed with lobes narrowly long-triangular and up to 2 cm long, red to pink-red, tube usually ribbed at the upper part; petals as many as calyx lobes, white or cream, 13–15 mm long, 2-lobed, each lobe with 3–4 long bristles, outer margins fringed with white silky hairs especially at the base; stamens in pairs embraced by the petals up to 11 mm long, with linear anthers; ovary inferior, usually 3-celled, style about 15 mm long with filiform stigma. Fruit a campanulate berry enclosed by the calyx tube, 2–2.5 cm long, 1-celled and 1(–2)-seeded, viviparous. Seedling with cigar-shaped hypocotyl, slightly angular, 15–25 cm × 1.5–2 cm, with a blunt narrowed apex, perforating the apex of the fruit and falling with it.

Other botanical information *Bruguiera* comprises 6 species, which are all used outside Africa in the same way as *Bruguiera gymnorhiza*. The other species are widespread from tropical Asia to Australia and Polynesia in mangrove vegetations, and their barks usually contain less tannin.

Anatomy Wood-anatomical description:

- Macroscopic characters:
  Heartwood red-brown, distinctly demarcated from the pale brown sapwood. Grain usually interlocked. Texture fine and even. Growth rings indistinct; vessels small and indistinct to the naked eye; parenchyma indistinct even with a lens; rays generally visible.

Growth and development *Bruguiera gymnorhiza* is viviparous, i.e. the seeds germinate while still attached to the tree. After the seedlings are released they fall vertically into the mud and become established rapidly. The tree develops according to Aubréville's model of architecture characterized by a monopodial trunk having rhythmic growth and plagiotropic branches. It takes 40 years to attain 16 cm in bole diameter. *Bruguiera gymnorhiza* is one of the largest trees of the mangrove and probably the one living longest. Growth decreases with decreasing salinity, which happens in the process of sedimentation in mangrove forest. In eastern Africa *Bruguiera gymnorhiza* usually does not grow over 25 m, but on Chale Island (southern Kenya) specimens reach a height of over 30 m. Flowering is mainly from January to March and fruiting from April to July. The flowers are visited by birds such as honey eaters and by insects. The pouched petals 'explode' when triggered, scattering pollen on the visitor. The fruits (seedlings) are dispersed by water. They can remain alive, floating in the water, for 5–6 months, which may explain the large area of distribution.

Ecology In eastern Africa, *Bruguiera gymnorhiza* is a component of mangrove vegetation consisting of 8–9 species. It is characteristic of the landward side of mangroves and can grow along the river beds upward as far as the tidal range, but it also is a common element of mangrove assemblages in the mid-intertidal zone inundated by normal high tides (or in some cases by spring tides only), where it is often mixed with *Rhizophora mucronata* Poir. and *Ceriops tagal* (Poir.) C.B.Rob. Although *Bruguiera gymnorhiza* is not recognized as a pioneering mangrove species, propagules from the tree are often found on exposed beaches where the mangrove belt is thin or depauperate. It usually grows on somewhat dry, well-aerated soil but also on mud, sand and occasionally black, peaty soils. It tolerates a pH of 6–8.5. *Bruguiera gymnorhiza* marks the climax vegetation of littoral mangrove forests, before the transition to land forest. It is shade tolerant and able to establish itself even in pure stands of *Rhizophora*. The regeneration after felling is usually scant or even absent. The temperature range for growth is 15–30°C with the optimum between 20–26°C. The annual rainfall range for growth is 1000–8000 mm with the optimum between 1500–2500 mm. *Bruguiera gymnorhiza* withstands flooding with fresh as well as salt water (maximum up to 3% NaCl), but is usually absent from the area nearest to the seaward edge.

Propagation and planting Natural regeneration of *Bruguiera gymnorhiza* is usually very common. Propagation by cuttings is very difficult and trees suffer when branches are taken off. Seedlings can be collected either from the trees or from the ground and they are equally viable. They can be planted in a nursery and transferred to the field 3–4 months later, at a space of 3 m × 1 m. Nurseries outside the mangrove forest should be made by planting fruits in polythene bags filled with brackish clay continuously soaked with seawater or a solution of approximately 30 g NaCl per l water. Seedlings develop best where the tidal range is only about 35 cm and the salinity 1–2.5%.

Management Little is still known about the silvicultural management of mangrove forests and little experimental work has been done on natural and artificial regeneration. In general, clear felling with natural regeneration can be carried out in strips perpendicular to the coast, leaving several mother trees. For *Bruguiera gymnorhiza* cutting cycles of 10–20 years have been suggested, but a rotation of 30 years is applied in mangrove forests in Thailand. *Bruguiera gymnorhiza* does not coppice. In mangrove forest the fern *Acrostichum aureum* L. becomes a weed and has to be controlled after the forest has been logged. Once seedlings have established themselves, the fern acts rather as a nurse, forcing the seedling up. Cutting *Bruguiera gymnorhiza* to extract tannin and produce charcoal leads to a gradual transformation into a *Rhizophora*-dominated vegetation. The slow growth of *Bruguiera* makes it more suitable for planting for charcoal or chipwood than for sawn timber. Experiments in Indonesia have shown that *Bruguiera gymnorhiza* can easily be planted and grown. It might be successfully used for reafforestation in areas where mangroves have been destroyed.

Diseases and pests No serious diseases or pests are known for *Bruguiera gymnorhiza*. Seedlings may be attacked by mangrove crabs like *Scylla serrata*, *Sesarma meinerti* and *Sesarma smithii*. Sometimes plantations may suffer from caterpillars.

Harvesting *Bruguiera gymnorhiza* is mostly harvested from natural stands. There is no particular season for bark harvesting. After the trees have been felled, the bark is separated from the wood and air-dried.

Yield A good mangrove stand can have an annual wood productivity of 10–20(–25) m³ per ha for all species. The yield of bark per ha from *Bruguiera gymnorhiza* is unknown.

Handling after harvest Chopped bark can be used directly in the tannery or the tannin can be extracted by boiling the bark in large vessels and evaporating down to a solid brown-black mass, called 'cutch'. Boiled bark or dissolved cutch can both be used for dyeing textile fibres and leather in various shades of orange to reddish brown (without mordant or with an alum mordant), and in grey to black if an iron mordant is used.

Genetic resources *Bruguiera gymnorhiza* is widespread and not yet in direct danger of genetic erosion. In eastern tropical Africa, including the Indian Ocean islands, about 10,000 km² mangrove vegetation is present. Tanzania, Mozambique and Madagascar are the countries with largest mangrove areas. About 25 areas are protected, but in many regions mangroves are threatened. They are over-exploited for timber or are cleared to make way for rice or shrimp farms, salt pans and urban development. These ecologically important habitats are also threatened by untreated waste discharged into rivers, industrial pollution and pesticides contained in run-off from farms. Dams constructed in rivers that flow into mangrove habitats have decreased the flow of water causing the salt content to increase to unnaturally high levels. Mangroves are also vulnerable to natural stresses such as river floods, deposition of sand and sediments, and rising sea levels. The decline of mangrove forests along the East African coast is mainly due to over-exploitation for charcoal, firewood, timber, dyeing and tanning materials without replanting. All these issues should be included in future mangrove management and reforestation plans.

Prospects The use of *Bruguiera gymnorhiza* bark for tanning may only remain important locally. The possibilities to only use the leaves and small branches as tannin and dye sources for local uses without damaging or cutting down the trees should be considered. In a broader perspective, the main issue is a rationalized use of mangrove forests. This will mean changes to present approaches in mangrove management. Problems to overcome are the lack of community input into management approaches, high levels of poverty within indigenous coastal communities, a general lack of awareness of the true value of mangroves, and over-utilization for charcoal, firewood, timber, tanning and dyeing materials. There has been no reforestation done in areas where mangroves have been exploited. Management policies have been introduced to control and prohibit destruction of mangrove forests, but there are few or no means available for their implementation. Knowledge of many aspects of mangrove ecosystems needs to be improved. Proper techniques for natural and artificial regeneration need to be developed, and more information is needed on growth and development.

Major references Coates Palgrave, 1983; Rudjiman, 1991a; Saberi Othman, 1998; Taylor, Ravilious & Green, 2003; Torre & Gonçalves, 1978.

Other references Arènes, 1954; Beentje, 1994; Boonkerd & Chan, 1997; Chan & Boonkerd, 1997; Decary, 1946; Friis, 1993; Gonçalves & Torre, 1979; Gurib-Fakim, Guého & Bissoondoyal, 1997; Hou, 1958; Lewis, 1956; Porter, 1994; Tomlinson, 1986; Watt & Breyer-Brandwijk, 1962; Williams, 1949.

Sources of illustration Saberi Othman, 1998.

Authors V.N. Mainga

Based on PROSEA 3: Dye and tannin-producing plants.

BUCHNERA HISPIDA Buch.-Ham. ex D.Don

Protologue Prodr. fl. nepal.: 91 (1825).

Family Scrophulariaceae (APG: Orobanchaceae)

Chromosome number $n = 14$

Synonyms *Buchnera longifolia* Klotzsch (1861).

Origin and geographic distribution *Buchnera hispida* is widespread in tropical Africa and subtropical southern Africa, Madagascar and Comoros, and through Yemen and Oman to India.

Uses The whole plant of *Buchnera hispida* turns blue-black if bruised and becomes black after drying. The dried powdered plant is used as source of a black dye for skin and textiles in Gambia. In Tanzania dried powder is mixed with castor oil and applied externally to treat scabies and eczema.

Properties No information on the phytochemistry of *Buchnera hispida* appears to be available, but several *Buchnera* species contain iridoids which, if also present in *Buchnera hispida*, could contribute to its colouring action.

Botany Facultative hemiparasitic, erect annual herb up to 1 m tall with simple or branched, hairy or scabrid stem. Leaves in a rosette at base in young plants, alternate on the stem, simple, sessile, rigid-hairy to scabrid; stipules absent; rosette leaves elliptical to almost circular, 2–3.5 cm × 1.5–2 cm, margin entire, 3-veined with a pinnately divided midrib; lower stem leaves ovate-lanceolate to oblong, 4.5–7.5 cm × 1–2.5 cm, margin entire to coarsely irregularly toothed, 3-veined with midrib pinnately divided; upper stem leaves linear-lanceolate, 1.5–4 cm × 1–2.5 mm, margin entire to remotely dentate, 1-veined. Inflorescence a terminal lax spike up to 25(–40) cm long; bracts leaf-like. Flowers bisexual, regular, 5-merous, nearly sessile; calyx tubular, 4–8 mm long, 10-veined, rigid-hairy, lobes 1–2 mm long; corolla tubular, tube cylindrical, up to 7.5 mm long, hairy, lobes equal, blue, purple or white, throat villous; stamens 4, inserted on corolla tube, included, 2 slightly longer than other 2; ovary superior, 2-celled, style filiform, stigma club-shaped to cylindrical. Fruit an ovoid capsule up to 5.5 mm × 3 mm, many-seeded. Seeds longitudinally striate.

Buchnera comprises about 100 species and occurs mainly in the tropics of the Old World, with about 90 species in tropical Africa. It is closely related to *Striga*, which comprises parasitic plants that are more destructive to crops.

Buchnera leptostachya Benth. is also used as a dye in Gambia, and as an ear medicine in Tanzania. It is an annual or perennial, almost glabrous herb up to 50 cm tall, with pink, blue or white flowers slightly smaller than those of *Buchnera hispida*, and it is found throughout tropical Africa, often in wet grasslands and coastal bushland, often on saline soils.

Buchnera hispida is a facultative hemiparasite; when no host plant is available it can flower and fruit independently, but with a host its growth is better. It requires light for germination. Although dark incubation in water before illumination is not absolutely necessary for germination, in tests it caused the seeds to respond more rapidly to light. The longer the time of the dark incubation the more responsive the seeds were to light.

Ecology *Buchnera hispida* is a weed of cultivated land which can parasitize roots particularly of cereal crops, e.g. sorghum, millet and maize, but is hardly ever a serious noxious weed. It is also found in well-drained grassland on sandy soils, often in open woodland, from sea-level up to 1800 m altitude.

Genetic resources and breeding *Buchnera hispida* is widespread and not in danger of genetic erosion.

Prospects *Buchnera hispida* as a source of dye will remain only very locally of some importance. Its medicinal properties need further investigation for evaluation.

Major references Burkill, 2000; Philcox, 1990.

Other references Hepper, 1963; Nwoke & Okonkwo, 1974; Nwoke & Okonkwo, 1980; Okonkwo & Nwoke, 1974; Wongsatit Chuakul, Noppamas Soonthornchareonnon & Orawan Ruangsomboon, 2003.

Authors P.C.M. Jansen

CAESALPINIA CORIARIA (Jacq.) Willd.

Protologue Sp. pl. 2(1): 532 (1799).

Family Caesalpiniaceae (Leguminosae – Caesalpinioideae)

Chromosome number $2n = 24$

Vernacular names Divi-divi (En). Dividivi (Fr).

Origin and geographic distribution *Caesalpinia coriaria* is native to tropical America and the West Indies. It has been introduced as an ornamental in other tropical regions and sometimes also for tanning, e.g. in India. In tropical Africa it has been recorded from Ghana, DR Congo, Uganda, Tanzania, Mozambique and Mauritius, and is very locally naturalized (e.g. in Mauritius).

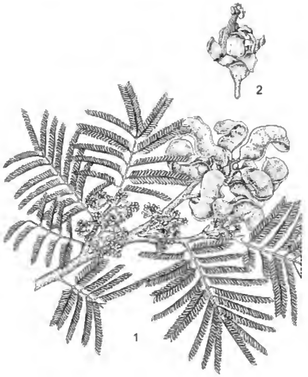
Uses The pods of *Caesalpinia coriaria* are very rich in tannin and are used in the tanning industry. The tan stuff from the pods is generally used as a blend for tanning leather, mixed with other tanning materials. Divi-divi is often used in rapid drum tanning of light leathers and in leather dressing. The pods are also used to prepare a blackish or bluish dye for cotton and wool and a black ink, used e.g. in the decoration of traditional potteries and gourds in Central America. They are sometimes employed as a mordant for dyeing vegetable fibres with other dyes. In medicine the pods are used as an antiperiodic and for dressing sores. The wood has been reported as having been used in Andhra Pradesh (India) as source of a red dye. *Caesalpinia coriaria* is used as an ornamental and shade plant and its leaves as a mulch.

Production and international trade *Caesalpinia coriaria* has been used in Central America for many centuries as a tanning material. Commercial supplies of divi-divi pods were obtained almost entirely from tropical America with Venezuela and Colombia as the major suppliers. Recent figures are not available, but in the 1950s annual exports of dry fruits varied from 3000–10,000 t from Venezuela and from 1000–7500 t from Colombia. India was much less important as a producing country, exporting 150–400 t/year in the 1910s and 1920s. The largest consumers were the United States and Germany. The use of divi-divi as a tanning material strongly declined after 1950 in favour of other vegetable materials and synthetic tanning substances.

Properties The pods (without seeds) of *Caesalpinia coriaria* contain 40–45% tannins composed of gallotannin and ellagitannins: corilagin, chebulagic acid and neo-chebulagic acid. Divi-divi extracts are liable to deteriorate rapidly; especially in hot climates fermentation takes place readily because of the large amount of sugars present; this often results in reddish stains in the leather. Divi-divi extracts produce a pale coloured leather, which is easily affected by atmospheric conditions, being soft and spongy under damp conditions and lacking pliability under dry conditions. Because of these disadvantages, divi-divi is usually used in mixtures with other tanning substances.

When tested in ponds, the tannin from divi-divi pods showed algicidal activity. Aucubin compounds have been identified. The wood of *Caesalpinia coriaria* is very hard, reddish brown. Seeds contain 5–9% of a fixed oil, about half of which consists of cyclopropenoid fatty acids, which have carcinogenic properties. Oven-dried fruits applied at 2.5 g/l were 100% effective in controlling the fresh-water snails *Lymnaea luteola* and *Gyraulus convexiusculus* within 24–72 h.

Botany Crooked and spreading small tree, usually up to 10 m tall, but sometimes much taller. Leaves alternate, bipinnate, pinnae in 3–9 pairs; leaflets in 12–28 pairs per pinna, sessile, oblong-linear, 4–10 mm × 1–2.5 mm, with black dots beneath. Inflorescence an axillary raceme or panicle 2–4 cm long. Flowers bisexual, zygomorphic, 5-merous, fragrant; sepals free, imbricate, usually unequal, the



Caesalpinia coriaria – 1, flowering and fruiting branch; 2, flower.
Source: PROSEA

lowest one hood-shaped; petals free, unequal, 3–4 mm long, pale yellow, the upper one different in shape and size; stamens 10, free, subequal, filaments hairy at base; ovary superior, 1-celled, style slender, stigma truncate. Fruit an indehiscent pod, flexuous and twisted, (2–) 5–8 cm × 1–3 cm, pale to blackish brown, 1–10-seeded. Seeds ellipsoid or reniform, 6–7 mm long, glossy brown.

The large genus *Caesalpinia* (about 200 species) is pantropical, the greater part of the species occurring in South and Central America. In tropical Africa about 25 species are indigenous, naturalized or cultivated.

Ecology *Caesalpinia coriaria* tolerates a wide range of soil types and climates. It grows on rich clay soils and poor sandy soils with pH 4.5–8.7, and thrives in dry (warm) temperate climates to wet tropical climates with an annual precipitation of 600 mm up to over 4000 mm, and a mean annual temperature of 15–28°C. In natural conditions in Central and South America, it is found in semi-arid, open country. Trees are reported to yield less under very moist tropical conditions than under drier conditions. At higher altitudes they do not yield well either.

Management Divi-divi is propagated by seed. In India the seedlings of divi-divi are kept in the nursery for 9–15 months, and then transplanted into the field, usually at the beginning of the rainy season, at distances of 7–9 m. During the first two years, watering is necessary in the dry season. Mature trees require very little care, and forage crops can be planted between the trees. Trees are relatively slow growing and generally commence flowering 5–7 years after sowing. Full crops of pods are produced after about 20 years. Some fungi are known to attack divi-divi: *Fomes lucidus*, *Micropeltis domingensis* and *Zignoella caesalpiniae*. The pods of divi-divi are collected before or after they drop from the tree. Trees yield about 45–135 kg pods per year. Because divi-divi pods are curved, they are voluminous, which makes transport expensive. The pods are usually packed in fine mesh bags. The tannins can easily be extracted. They are mainly present in the white powdery tissue just below the epidermis of the pod, and this tissue is easily collected when the dry pods are ruptured. The powder has the drawback of being slightly hygroscopic and should be packed in sealed containers. It is susceptible to rapid deterioration but fermentation can be minimized by the use of antiseptics.

Genetic resources and breeding *Caesalpinia coriaria* is widespread and not in danger of genetic erosion. Germplasm collections are not known to exist.

Prospects In Africa *Caesalpinia coriaria* is not well known as a tannin-producing plant and it is not likely that it will become important in the future. However, the fact that it is a source of reasonable quality tanning material, especially when used in mixtures, and a good source of black dye and ink, may offer possibilities since sustainable production is possible, the part of the plant used being the seeded fruits.

Major references Boonkerd, Na Songkhla & Thephuttee, 1991; CSIR, 1950; Duke, 1981.

Other references Bali, Sawai Singh & Pati, 1985; Brenan, 1967; Cardon, 2003; Ibnu Utomo, 2001; Polhill, 1990.

Sources of illustration Boonkerd, Na Songkhla & Thephuttee, 1991.

Authors P.C.M. Jansen

Based on PROSEA 3: Dye and tannin-producing plants.

CAESALPINIA SAPPAN L.

Protologue Sp. pl. 1: 381 (1753).

Family Caesalpiniaceae (Leguminosae – Caesalpinioideae)

Chromosome number $2n = 24$

Vernacular names Sappanwood, Indian redwood (En). Sappan, bois de sappan (Fr). Pau de sapan (Po).

Origin and geographic distribution The origin of *Caesalpinia sappan* is not certain, but it is thought to be in the region from central and southern India through Myanmar and Thailand to Peninsular Malaysia and to Indo-China and southern China. It is cultivated and naturalized in many parts of the tropics. In Africa it has been recorded from Nigeria, DR Congo, Uganda, Tanzania, Réunion, Mauritius and South Africa.

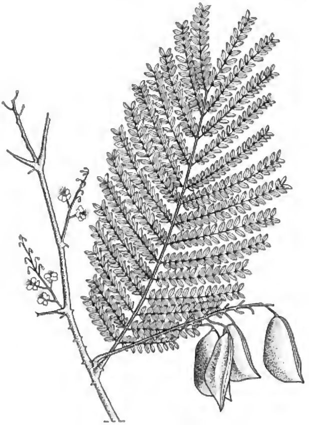
Uses The wood of *Caesalpinia sappan* is the wood-dye that is known to have been used at a large, international scale throughout world history. Hundreds of tonnes were exported annually to the Islamic and Mediterranean worlds and Europe from the Middle Ages onwards. It remained a major source of red dye up to the end of the 19th century. It is still used for dyeing textiles, but only on a smaller scale by craftsmen and artists. Silk, wool, cotton, matting and basket fibres can be dyed red with it and it is also used occasionally to colour food. The wood is ground into a coarse powder, moistened with water and allowed to ferment for a few weeks to increase the colouring power of the dye. The fermented wood is boiled in water. The dye liquor may be used immediately or evaporated to be commercialised as a dry soluble extract which can be stored for future use. The mordants used (e.g. aluminium acetate, stannic salts, oxalic acid) determine the final colour of the cloth, which can vary from shades of red to pink, violet and brown. Sometimes the dye is used in combinations, for instance on top of a blue indigo dye-bath for purple colours and with turmeric and iron sulphate to produce a rich maroon. The dye can also be extracted with alcohol and other organic solvents. A few drops of wood extract in drinking water is considered refreshing, due to the fragrance and colour it imparts.

The fruits contain tannin and were used in the past to prepare a black dye in combination with an iron mordant. The wood has been used in cabinet-making since mediaeval times, especially for inlay decoration. It also is a good source of firewood. *Caesalpinia sappan* is often planted as a living fence and ornamental. Owing to its easy growth and dense growth habit, it is used for defining the boundaries of land and for protecting plantations against grazing animals. The leaves can be used to hasten ripening of fruits such as bananas and mangoes. Sappanwood is also used in the traditional medicines of various Asiatic countries (India, Vietnam, China, Japan). A decoction or infusion of the heartwood is generally considered a strong emmenagogue and astringent. It is also used to cure wounds (also with a plaster of macerated leaves and bark), tuberculosis, diarrhoea and dysentery and is reported as having antioxidative, anti-inflammatory, hepatoprotective, cytotoxic, hypoglycaemic and xanthine oxidase-inhibitory activities. The seeds serve as a sedative.

Properties The main extractable component, called sappanin, amounts to 20% of the oven-dry weight of the heartwood. The main dye component in the heartwood of *Caesalpinia sappan* is brazilin, also present in brazilwood (*Caesalpinia echinata* Lam.). Brazilin is a weakly coloured product, which easily oxidises to give the deep red pigment brazilein, natural red number 24 and dye number 75280 of the Colour Index. Several other phenolic compounds have also been isolated from the heartwood and contribute to the dye properties of the wood: mostly 3'-O-methylbrazilin and other homoisoflavonoids (sappanol and methylderivates, episappanol and derivates, sappanones A and B), various dibenzoxocins (protosappanins A, B and C) and a dimeric methanodibenzoxocinone, neosappanone A. The majority of these compounds are transformed into brazilin by heating, in the weak acidic or basic media resulting from the current dye-extraction processes. In tests, brazilin had a positive effect on the immune functions in the early phase of halothane intoxicated mice and had a hypoglycaemic action and increased glucose metabolism in animals presenting experimentally induced diabetis. A decoction of the wood showed antibiotic activity against *Staphylococcus*, *Salmonella typhi*, *Shigella flexneri*, *Shigella dysenteriae* and *Bacillus subtilis*. An extract of *Caesalpinia sappan* was found to be a potent agent for inactivating human sperm in vitro; about 2.5 mg/ml is required to reduce motility to 50%.

The stem and leaves contain alkaloids and tannins, abundant saponin and phytosterol. The fruits contain c. 40% tannin, which is suitable for the production of light leather goods. Freshly cut sappanwood is pale orange in colour. The colour deepens to dark red upon prolonged exposure to sunlight or air. Prolonged boiling intensifies the colour of the dye. The sapwood ring is very narrow and pale, the heartwood makes up to 90% of the total volume. The pith is distinct and yellowish. The growth rings are distinct. The wood is straight grained with a fine to moderately fine texture, fairly heavy (600–780 kg/m³), hard and lustrous. It is difficult to dry and is susceptible to warping and collapse, but moderately easy to work; it takes a high finish, and is tough and resistant to termite attack. The energy value is about 25,000 kJ/kg.

Botany Shrubby tree up to 10 m tall; trunk up to 14 cm in diameter, bark with distinct ridges and many prickles, greyish brown; young twigs and buds hairy, brownish. Leaves stipulate, bipinnate, up to 50 cm long, with 8–16 pairs of pinnae; pinnae with prickles at the base and with 10–20 pairs of sessile leaflets; leaflets oblong, 1–2 cm × 0.5–1 cm, very oblique at base, rounded to emarginate at apex. Inflorescence an axillary or terminal panicle or raceme 10–40 cm long. Flowers bisexual, slightly zygomorphic, 5-merous, 2–2.5 cm wide when open, yellow; sepals glabrous; petals pubescent, the superior one smaller; stamens 10, filaments woolly-hairy in the lower half; ovary superior, pubescent, 1-celled. Fruit a dehiscent pod, cylindrical-obovate, 7–9 cm × 3–4 cm, strongly flattened, shiny and glabrous with curved beak at apex, yellowish green when young, maturing to reddish brown, 2–5-seeded. Seeds ellipsoid, flattened, 18–20 mm × 10–12 mm, brown.



Caesalpinia sappan – flowering and fruiting branch.
Source: PROSEA

The large genus *Caesalpinia* (about 200 species) is pantropical, the greater part of the species occurring in South and Central America. In tropical Africa about 25 species are indigenous, naturalized or cultivated.

Initially sappanwood grows straight but after having attained a height of about 2.5 m, the branches start to droop and entwine with the branches of nearby trees to form thickets, generally free from undergrowth. After the tree is felled the stump sprouts profusely within two weeks. Flowering can occur after one year of growth. Flowering is usually in the rainy season, fruiting about 6 months later.

Ecology Under natural conditions *Caesalpinia sappan* grows mostly in hilly areas with clayey soil and calcareous rocks at low and medium altitudes. It does not tolerate too wet soil conditions. Sappanwood tolerates an annual precipitation of 700–4300 mm, a mean annual temperature of 24–28°C and a soil pH of 5–7.5.

Management Sappanwood can be propagated by seed and renewed by coppicing. Usually mature pods burst open in the dry season and scatter the seeds, which remain dormant until the start of the rainy season. Seeds germinate immediately if enough moisture is available. The germination rate is enhanced to about 90% by dipping the seeds into boiling water for 5 seconds. Usually the plants are grown in the shade of trees in the forest or in forest borders.

No serious diseases and pests have been reported, although fungi such as *Auricularia auricula-judae* (the edible Judas ear mushroom) and *Meliola caesalpiniae* can attack the trees. For use as a dyewood the tree must be harvested every 6–8 years, to allow the heartwood to become fully developed; for firewood it may be harvested every 3–4 years when the trunk has attained a diameter of 5–6 cm. The tree is cut about 1 m above the ground to allow sprouts to grow from the stump. Harvesting is done manually with a machete; prickles are easily removed by brushing with the blunt edge of the machete.

Genetic resources and breeding *Caesalpinia sappan* is widely planted and not in danger of genetic erosion.

Prospects A big scale revival of the use of sappanwood as a dye source for the textile industry will probably not happen in the immediate future since synthetic dyes are still cheaper to produce, often brighter, and the best ones can compete with natural dyes for light and washing fastness. However, natural dyes may regain some of their former importance because of environmental and toxicity problems connected with the production and use of synthetic dyes, and the gradual exhaustion of the fossil materials synthetic dyes are made from. Sappanwood would then provide a renewable source of colorant, not only in the textile and basket-weaving crafts but also in the food, cosmetic and pharmaceutical industries. Sappanwood may have even better prospects as a medicinal plant, and will go on being valued for its beautiful wood in cabinet-making as well as a source of fuelwood with high energy value.

Major references Zerrudo, 1991.

Other references Cardon, 2003; Choi et al., 1997; Duke, 1981; Fuke et al., 1985; Gurib-Fakim, Guého & Bissoondoyal, 1995; Ibnu Utomo, 2001; Oh et al., 1998; Polhill, 1990; Shih et al., 1990; Viaux-Locquin, 1997; Zerrudo, 1985.

Sources of illustration Zerrudo, 1991.

Authors P.C.M. Jansen

Based on PROSEA 3: Dye and tannin-producing plants.

CERIOPS TAGAL (Perr.) C.B.Rob.

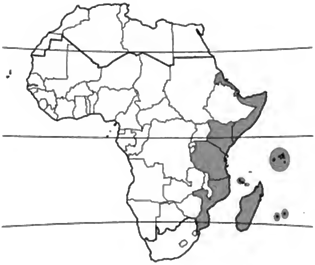
Protologue Philipp. Journ. Sci., Bot. 3: 306 (1908).

Family Rhizophoraceae

Chromosome number $2n = 36$

Synonyms *Ceriops candolleana* Arn. (1838), *Ceriops boiviniana* Tul. (1856).

Vernacular names Yellow mangrove, spurred mangrove (En). Tengar (Fr). Mangal indiano (Po). Mkandaa, mkandaa ya pwani, mkoko mkandala, mkoko mwekundu (Sw).



Ceriops tagal – wild

Origin and geographic distribution It is not known where *Ceriops tagal* originated but it is now widespread and common on coasts from eastern Africa and the Indian Ocean islands to the Indian subcontinent and from there through tropical Asia to Australia and the Pacific. In Africa it extends as far north as the gulf of Suez in Egypt (28°N) and the gulf of Aqaba in Jordan (30°N). In eastern Africa it occurs along the coast of Eritrea south to Kosi Bay in South Africa. Extensive stands of *Ceriops tagal* occur in Maputo Bay in southern Mozambique (26°S), and it also occurs in the Indian Ocean Islands.

Uses The stem bark of *Ceriops tagal* is used for dyeing and tanning in eastern Africa and Asia. In fishing communities nets and sails are treated with a bark extract to preserve them from decay. In South-East Asia, the bark is a major ingredient for the famous 'soga browns' of Javanese batiks.

In Africa *Ceriops tagal* provides poles and planks for house building, small planks for boat building including paddles and oars, and fishing stakes. For house building it is preferred by many communities (e.g. the Giriama people in Kenya) because it grows long and straight and is suitable for making wattlework for walls and roofs. Communities living along the East African coast and islands also use it as a medium-quality commercial firewood. In some cases it is converted to charcoal, mainly from mangrove forests close to urban centres. The wood has been used as a source of pulp. An extract of the bark is used as a binder for particle board. Numerous applications in traditional medicine have been reported. The bark is used in lotions to treat malignant ulcers and abdominal ailments in Malaysia, and in the Philippines the bark is applied to cure diabetes. In general, bark extracts are used as an astringent, haemostatic and quinine substitute to cure malaria.

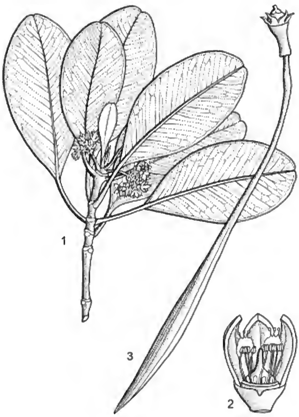
Production and international trade In general, mangrove forests are of considerable commercial value and they have been exploited for a long time along the East African coasts. Wood for ceilings, roofs and building poles (called 'boriti' in Swahili) are sold in the Persian Gulf and Red Sea, providing a very profitable trade.

Properties The tannin content of *Ceriops tagal* bark can vary considerably, from 13% to over 40%, a common and notable feature of mangrove barks. The tannins belong to the group of condensed tannins of the procyanidin type, the reason why dyeing with the bark gives reddish-brown colours. The leaves contain less tannin, about 15%, bark from twigs 25–41%. In India solid block extracts containing 68% tannin and 15% moisture, and powder extracts containing 75% tannin and 5% moisture, have been prepared for use in the tanning industry.

The sapwood is usually poorly defined, the heartwood is orange when freshly cut, but turns yellowish-brown or sometimes even red on exposure. The wood is heavy with an average density of 960 kg/m^3 at 15% moisture content. It is moderately durable but in contact with the ground it decays in about 2 years. The timber is not resistant to marine borers. Seasoned wood is comparatively resistant to splitting on shock and it is thus suitable for tool handles.

Adulterations and substitutes The bark of other mangrove trees is similarly used for tanning, timber and firewood, e.g. *Bruguiera gymnorhiza* (L.) Savigny and *Rhizophora mucronata* Poir.

Description Glabrous shrub or small tree up to 6 m tall (exceptionally up to 40 m tall with bole up to 40 cm in diameter) with grey to red-brown, sometimes deeply fissured bark; root system with some deeply descending roots and superficial roots radiating from trunk, with knee roots or pneumatophores; branches with elliptical to circular scars of the petioles of fallen leaves and annular scars of fallen stipules. Leaves decussately opposite, clustered at the end of twigs, simple and entire; stipules lanceolate, up to 2.5 cm long, deciduous; petiole 1–3.5 cm long; blade elliptical to oblong or obovate, 4–12 cm × 2–7.5 cm, base cuneate, apex rounded to retuse, leathery, pinnately veined but veins usually indistinct. Inflorescences an axillary condensed cyme, up to 10-flowered; peduncle up to 1.5 cm long, very shortly or obsoletely 2–3-forked at apex. Flowers bisexual, regular, 5-merous, sessile, with cupular bracts at base; calyx fleshy, reddish brown, with tube c. 2.5 mm long and triangular or ovate-triangular lobes c. 5 mm long, acute at apex; petals often cohering a little below the middle by the hooked-hairy margins, white or cream, oblong or obovate-oblong, c. 3.5 mm × 2 mm, apex truncate with 3 club-shaped, glandular appendages; disk composed of 5 separate, 2-lobed elements; stamens 10, filaments filiform, 3–4 mm long, white, anthers much shorter, explosively dehiscent; ovary semi-inferior, ovoid, 3-celled, style simple, thickened at base. Fruit an ovoid indehiscent berry 1.5–2.5 cm long, with persistent reflexed calyx lobes, usually 1-seeded. Seed germinating on the plant; hypocotyl club-shaped, up to 35 cm long, rounded to sharply longitudinally ridged and sharply pointed.



Ceriops tagal – 1, flowering branch; 2, flower with front sepals and petals removed; 3, fruit with protruding hypocotyl.
Source: PROSEA

Other botanical information *Ceriops* comprises 2 species. *Ceriops decandra* (Griff.) Ding Hou is found in tropical Asia and is vegetatively similar to *Ceriops tagal*, but has shorter inflorescences and hypocotyl. *Ceriops tagal* may occur intermingled with other mangrove trees such as *Bruguiera*, *Rhizophora* and *Xylocarpus* species, but it is easily distinguished by its glossy green, rounded (never pointed or apiculate) leaves, flattened buds, slender, comparatively short and ridged hypocotyls, and comparatively pale bark.

Anatomy Wood-anatomical description:

- Macroscopic characters:
  Heartwood brown to red with orange hues, without streaks, distinctly or indistinctly demarcated from the pale yellow sapwood. Grain straight. Texture very fine. Growth rings inconspicuous; vessels only visible with a hand lens, usually in radial multiples of 2–6, sometimes solitary; parenchyma visible with a hand lens as narrow sheaths to the vessels, winglike and confluent, or absent; rays not visible to the naked eye, usually as wide as or slightly wider than vessels; tyloses present or absent.

Growth and development The seed germinates while the fruit is still attached to the plant and develops a massive hypocotyl, which contains the food reserve for the seedling. The hypocotyl hangs down from the fruit with the true root at the end. The root has small outgrowths, which are the branch roots all ready to grow out. The plumule too is well-developed, but is enclosed in a sheath holding it in the fruit until the seedling drops from the tree. Seedlings fall like a dart to lodge upright in soft mud into which they penetrate to some depth. They become anchored by the outgrowth of the branch roots and so have a good chance of retaining a hold in the scour of the tide. The seedling is buoyant and if it does not stick in the mud where it drops because of a high tide or for some other reason, it may be transported by water. The seedling becomes established quite quickly. Upward growth carrying the seedling leaves above the level of the flood tide is very rapid and growth may be as much as 60 cm in 24 hours. Later the growth rate declines and seedling development can take a year. Seedlings are unbranched initially, and later branching is continuous or intermittent, depending on the vigour of the plant. In seasonal climates flowering is during the summer; from Kenya to Mozambique it occurs mainly from November to March. Flowers open mostly in the evening and remain open the following day, emitting a faint but fragrant odour. Pollination is probably by night-flying insects, although bees also visit the flowers at daytime. Pollen release is explosive and is triggered by delicately touching the petals, which each hold a stamen pair.

Ecology *Ceriops tagal* grows in saline creeks and mud flats just above sea-level, where pH ranges from 6 to 8.5, temperature from 20°C to 26°C and average annual rainfall from 750 mm to 1500 mm. Typically it occupies sites of the inner mangrove. There flooding with salt water is often infrequent, while soil salinity may be high due to evaporation. Under these circumstances *Ceriops tagal* may form pure stands. In Africa it occurs as a distinct zone along creeks, just landward of the *Rhizophora mucronata* zone. If occurring in seaward areas it is generally found behind *Sonneratia alba* Sm., *Avicennia marina* (Forssk.) Vierh. and *Rhizophora mucronata*. Sometimes it is found along smaller channels in muddy sea shores which have sandy banks and receive less fresh water, or in intertidal mud flats and estuaries. It may also grow on frequently flooded fossil coral rock.

Propagation and planting *Ceriops tagal* can be propagated by planting seedlings or pneumatophores. Unlike in other *Rhizophoraceae*, the seedlings are small and delicate and should be collected and transported to the planting areas with care. Seedlings do not tolerate excessive desiccation, but they establish quickly. Cut stems do not resprout. Natural regeneration of *Ceriops tagal* is very successful and where it grows additional planting is usually not needed.

Diseases and pests *Ceriops tagal* is often attacked by some mistletoes. Many herbivores are discouraged by the high tannin content. Crabs feed on the seedlings. Monkeys such as Sykes monkey (*Cercopithicus mitis*) cause a minor damage by uprooting seedlings. *Oecophylla* ants are common on *Ceriops tagal* leaves and other mangrove species in Australia. They feed on sugar secretions of coccid bugs, that suck mangrove sap. *Oecophylla* ants have also been observed on mangroves at Inhaca Island in southern Mozambique.

Harvesting There is no particular season for harvesting the bark. When harvested for firewood, trees are often killed by indiscriminate lopping of branches.

Handling after harvest For tanning purposes the bark of older *Ceriops tagal* trees is preferred because the tannin content increases with age. The bark is peeled off and may be used directly, but in India tanning extracts may be prepared from it, and marketed as blocks or powder. *Ceriops tagal* bark is often used in a mixture of bark from several mangrove species prepared for a tanning extract.

In central Java the fine 'soga-batik' is still made using vegetable dyes, although on a small scale. The bark of *Ceriops tagal*, usually called 'tingi', is one of the ingredients of the traditional dye-recipes, together with the wood of *Maclura cochinchinensis* (Lour.) Corner and the bark of *Peltophorum pterocarpum* (DC.) Backer ex K.Heyne. Depending on various proportions of the ingredients, cotton cloth is dyed yellowish to brownish shades in traditional patterns, in a process which often takes several weeks. After the dyeing process, a fixing bath containing lime, sugar, and traditionally also alum and flower buds of *Sophora japonica* L. or borax, palm molasses, alum, annatto and lemon juice, is necessary to make the colours more fast and bright. Using this dyeing process, warm yellowish-brown colours, gradually shading off into one another, are given to the cotton cloth. These effects cannot be achieved when using synthetic dyes. Top-dyeing with soga-dye of textiles or parts of textiles already dyed with indigo produces shades of purple and black.

Genetic resources *Ceriops tagal* is widespread and not yet in direct danger of genetic erosion. In eastern tropical Africa, including the Indian Ocean islands, about 10,000 km^2 mangrove vegetation is present. Tanzania, Mozambique and Madagascar are the countries with largest mangrove areas. About 25 areas are protected, but in many regions mangroves are threatened. They are over-exploited for timber or are cleared to make way for rice or shrimp farms, salt pans and urban development. These ecologically important habitats are also threatened by untreated waste discharged into rivers, industrial pollution and pesticides contained in run-off from farms. Dams constructed in rivers that flow into mangrove habitats have decreased the flow of water causing the salt content to increase to unnaturally high levels. Mangroves are also vulnerable to natural stresses such as river floods, deposition of sand and sediments, and rising sea levels. The decline of mangrove forests along the East African coast is mainly due to to over-exploitation for charcoal, firewood, timber, dyeing and tanning materials without replanting. All these issues should be included in future mangrove management and reforestation plans.

Prospects Management policies have been introduced to control and prohibit destruction of mangrove forests but there are few or no means available for their implementation. Therefore, stricter local governmental regulations and their enforcement are necessary for the protection of mangroves, while at the same time involvement of local communities in sustainable management and protection of the mangrove forests is essential. Only under such conditions can the use of the bark of *Ceriops tagal* and other mangrove species for dyeing and tanning be recommended as a truly renewable resource.

Major references Barbosa, Cuambe & Bandeira, 2001; Cardon, 2003; CSIR, 1950; Dahdouh-Guebas et al., 2000; Diop (Editor), 1993; Hogarth, 1999; Hughes & Sukardjo, 1991; Kairo et al., 2002; Tomlinson, 1986.

Other references Bandaranayake, 1998; Kalk (Editor), 1995; Lewis, 1956; Lind & Morrison, 1974; Mwangi Theuri, Kinyamario & Van Speybroeck, 1999; National Academy of Sciences, 1980; Perry, 1980; Richter & Dallwitz, 2000a; Taylor, Ravilious & Green, 2003; Torre & Gonçalves, 1978; Watt & Breyer-Brandwijk, 1962; White, 1983b.

Sources of illustration Hughes & Sukardjo, 1991.

Authors B.K. Maundu & S.O. Bandeira

COCHLOSPERMUM TINCTORIUM Perr. ex A.Rich.

Protologue Fl. Seneg. tent. 1(3): 99, t. 21 (1831).

Family Cochlospermaceae

Chromosome number $2n = 12$

Origin and geographic distribution *Cochlospermum tinctorium* is found from Senegal to southern Sudan and Uganda.

Uses The rootstock of *Cochlospermum tinctorium* is collected from the wild and yields a brown-yellow dye, used for dyeing cloth (cotton), thread, mats, basketware and ornaments, and rarely also leather. The fresh or dried rootstock may be pulverized and pounded into a paste that is rubbed onto the article to be dyed; it may also be crushed, mixed with ash and boiled with the article to be dyed. Several colours can be obtained by the use of mordants (e.g. *Striga asiatica* (L.) Kuntze) or by the addition of indigo. In Côte d'Ivoire, the Baoulé people add lemon juice to the dye-bath to improve the fastness of the dye. In Cameroon a yellow facial mask is made from the powdered rootstock mixed with water. The dye is also used to colour shea butter and cooking oil to which it possibly also imparts some flavour. Such butter and oil is said to stain the mouth and to cure burns. Unripe fruits are eaten by hunters to allay thirst. The floss of the fruit can be used to stuff cushions or, as is done in Togo, it is spun into necklace cords. The young stem bark also yields a useful fibre. In traditional medicine, the yellow rootstock is one of the most respected medicines in West Africa for jaundice and liver diseases. It is also applied to cure oedema, urethral discharge, dysmenorrhoea, epilepsy, schistosomiasis, pneumonia, bronchial affections, conjunctivitis, gastric problems, diarrhoea, indigestion, stomach-ache and skin infections. In Burkina Faso an extract of the rootstock is taken against malaria. In Nigeria a concoction of the fruits with tamarind fruits is drunk to cure snakebites, and in Côte d'Ivoire and Burkina Faso powdered rootstock is applied topically. In Côte d'Ivoire pulped leaves are used in a wet dressing to maturate abscesses and furuncles and a decoction of the twigs or rootstock is drunk or used in a bath to treat urino-genital disorders, kidney pain or pain between the ribs. The body is washed with a water extract of the rootstock to cure skin diseases and as prophylaxis. In Nigeria the rootstock is also chewed as a tonic. The rootstock is also extensively used in veterinary medicine. Seed oil is used to treat leprosy. Its decorative flowers make the plant a potential ornamental.

Production and international trade There is some export of the dye of *Cochlospermum tinctorium* from Ghana.

Properties The rootstock of *Cochlospermum tinctorium* is rich in carotenoids that are the yellow pigments of the dye stuff; the rootstock also contains much mucilage, sugar, acetogenins, tannins (gallic acid, ellagic acid and ellagitannin), essential oils (alcohols, 3-hexadecanone), arjunolic acid and probably some alkaloid. The apocarotenoids cochloxanthin and dihydrocochloxanthin showed antimicrobial activity against *Candida albicans*, *Aspergillus fumigatus*, *Staphylococcus aureus* and *Escherichia coli*, but only at high concentrations. A methanolic rootstock extract showed antibacterial activity against some bacteria which are responsible for skin diseases. The tannins showed a remarkable antihepatotoxic activity and particularly gallic acid inhibits the production of oxygen-free radicals in leucocytes. An ethanol extract of the rootstock showed a pronounced antiplasmodial activity (1–2 µg/ml), with 3-O-E-p-coumaroylalphitolic acid as the most active compound. Leaf extracts showed moderate antiplasmodial activity. Tests on mice showed that arjunolic acid isolated from the rootstock has considerable inhibitory effects on skin tumour promoters. The leaves and shoots of *Cochlospermum tinctorium* are possibly toxic because it is said that cattle will not graze the plant even in times of shortage.

Botany Subshrub up to 80 cm tall with woody subterranean rootstock producing annual shoots. Leaves alternate, palmately (3–)5-lobed; stipules linear, caducous; petiole 3–6 cm long; blade in outline 2–12 cm × 2–16 cm, lobes lanceolate to oblong, basally connate for up to 1/4 of their length, margins entire to serrate, glabrescent to pubescent below. Inflorescence a few-flowered panicle or raceme, usually produced at ground level from the rootstock, sometimes appearing on top of leafy shoots. Flowers bisexual, regular, 5-merous, 6–9 cm in diameter; pedicel 1.5–4 cm long; sepals elliptical-oblong, 1–1.5 cm × 0.5–1 cm, velvety outside; petals obovate, 2.5–4 cm × 2–3 cm, shallowly emarginate, golden-yellow; stamens numerous, free; ovary superior, usually woolly, style simple, slender, stigma small. Fruit a fusiform or obovoid capsule 4–6 cm × 2.5 cm, slightly ridged, brown, grey or black, many-seeded. Seeds reniform, c. 5 mm long, densely covered with long white to yellowish hairs.

Cochlospermaceae is a small family, related to *Bixaceae*, and comprising 15 species in 2 genera. *Cochlospermum* comprises 12 species, 5 of these occurring wild in Africa. The roots of the African species *Cochlospermum angolense* Welw. ex Oliv. and *Cochlospermum planchonii* Hook.f. and of the American species *Cochlospermum regium* (Schrank) Pilg. and *Cochlospermum vitifolium* (Willd.) Spreng. yield a yellow dye which is used similarly to the dye of *Cochlospermum tinctorium*. The leaf shape in *Cochlospermum tinctorium* is variable, sometimes causing confusion with *Cochlospermum intermedium* Mildbr. from the Central African Republic. Annual leafy shoots are produced from the rootstock in the rainy season. Flowering is in the dry season after the savanna burns, and the fruits are ripe about one month after flowering. The flowers are usually produced near ground level, but in southern Sudan and Uganda they are often borne on top of leafy shoots.

Ecology *Cochlospermum tinctorium* occurs in dry savanna, preferring devastated, rocky and annually burnt regions, at 300–1500 m altitude.

Genetic resources and breeding *Cochlospermum tinctorium* is widespread and does not seem to be in danger of genetic erosion.

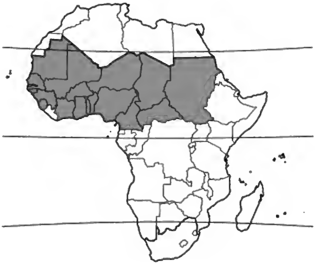
Prospects *Cochlospermum tinctorium* will remain locally an important dye plant. Its interesting medicinal properties may make it a valuable medicinal plant of much wider importance.

Major references Burkill, 1985; Burkill, 2000; Neuwinger, 1996; Poppendieck, 1980; Silva et al., 1996.

Other references Benoit et al., 1995; Benoit-Vical et al., 1999; Benoit-Vical et al., 2001; Bisignano et al., 1996; Diallo et al., 1989; Diallo et al., 1995; Diallo et al., 1991; Miège, 1992; Nacoulma-Ouédraogo & Millogo-Rasolodimby, 2002; Verdcourt, 1975a; Zederkopff-Ballin et al., 2002.

Authors P.C.M. Jansen

COMBRETUM GLUTINOSUM Perr. ex DC.



Combretum glutinosum – wild

Protologue Prodr. 3: 21 (1828).

Family Combretaceae

Chromosome number $2n = 26$

Synonyms *Combretum passargei* Engl. & Diels (1899), *Combretum relictum* (Aubrév.) Hutch. & Dalziel (1927).

Vernacular names Bois d'éléphant, chigommier (Fr).

Origin and geographic distribution *Combretum glutinosum* is widespread all over West Africa and extends to Sudan.

Uses In West Africa, particularly from Senegal to Côte d'Ivoire, the leaves, stems and root bark of *Combretum glutinosum*, collected from the wild, are important sources of yellow to brownish yellow dyes for cotton textiles. In Burkina Faso, Benin and Nigeria, these dyes are also used to dye leather and mats made of various vegetable fibres. The main importance of *Combretum glutinosum* (called 'càngàra bilen' in Bamanankan, Mali) however, is in the preparation of the internationally renowned 'bogolanfini' or 'bogolan' textiles ('mudcloth') of Mali, where other tannin-rich plants are also used, depending on the local resources and traditions. *Combretum glutinosum* is much used in the Bélédougou region, north of Bamako. The black designs of bogolan are obtained by the reaction of plant tannins with iron salts contained in local fermented mud. While the basic process of making black dyes with tannin-plants and mordanting with iron-rich mud has been known all over the world and is still very much used in other parts of Africa for barkcloth and vegetable fibres, the special art of bogolan originally belongs to the women of several peoples of the Mande group: Bamanan, Dogon, Malinke, Minianka, Bobo and Senoufo. Formerly it was used to decorate garments for special groups of people and special occasions, imparting them symbolic protective and curative powers, but recently these cloths have attracted the attention of the international fashion world. Malian artists and fashion designers have adapted techniques and designs, generating an increasing worldwide demand.

Combretum glutinosum is also used in indigo dyeing; from Senegal to Nigeria, the wood ash is particularly appreciated to maintain the indigo vat at the optimum alkaline pH.

The fresh young leaves, though bitter-tasting, are occasionally eaten as a vegetable, in Senegal together with taro (*Colocasia esculenta* (L.) Schott), and furnish a useful forage relished by all stock in the Sahel zone. The wood is yellowish, hard and very durable and is used in house construction, for tool handles and as firewood. In Nigeria smoke of the wood is used for fumigation and as an incense. In traditional medicine *Combretum glutinosum* is highly valued. A decoction or infusion of the leaves, bark or fruits is very popular, mainly to treat urinary, liver and kidney complaints, but also all kinds of respiratory problems, fevers, intestinal complaints and to clean wounds and sores. Crushed or dry powdered leaves or bark are used as a dressing on wounds. The Maninka people take a leaf decoction in baths and by draught against general fatigue. In Senegal the gum of the bark is used to fill the cavity of a carious tooth. Young shoots and roots are believed to have aphrodisiac properties.

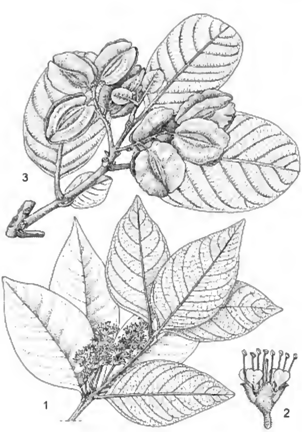
Production and international trade The increased interest and demand has made bogolan production an important economic activity with centres spreading from Mali to neighbouring countries, and with international markets, mostly in Europe and the United States. Wood ash from *Combretum glutinosum*, widely used in indigo dyeing, is traded for this use both at regional and international scale but statistics are not available.

Properties Gallic acid, ellagic acid, flavonoid glycosides and 4 tannins have been isolated from the leaves of *Combretum glutinosum*. The tannins are 2,3-(S)-hexahydroxydiphenoyl-D-glucose, punicalin, punicalagin and combreglutinin. The bogolan process is based on the reaction of the tannins with the soluble iron compounds present in the fermented mud, resulting in a black colour. In traditional bogolan, mud is applied everywhere, leaving only the fine lines of the designs mud-free resulting in a yellowish design on a black ground. The yellow colour imparted to the cotton cloth by the mixture of flavonoids and tannins present in the dye bath is later bleached, which was achieved formerly by an application of home-made soap using ash-lye, and is mostly done now with commercial bleaching agents.

Gum, present in the bark, consists of uronic acid compounds which hydrolyze to a number of sugars. Combreglutinin has interesting medicinal properties, particularly for the treatment of hepatitis B. Other proven medicinal effects of *Combretum glutinosum* are promoting discharge of urine, reduction of hypertension, discharge of bladder stone and antitussive and disinfectant properties of the leaves.

Adulterations and substitutes In the bogolan process, the leaves of *Combretum glutinosum* can be replaced by those of the more often used *Anogeissus leiocarpa* (DC.) Guill. & Perr. which have similar effects, giving yellow dyes that can be bleached easily to leave white designs on a black ground. The barks of *Lannea microcarpa* Engl. & K.Krause and *Terminalia macroptera* Guill. & Perr. are also used to dye bogolan textiles, but the ochre to reddish colours obtained are preserved, not bleached, giving textiles with reddish designs on a black ground or a reddish ground with black designs, the black colour being due in all cases to the reaction of the various tannins present in the plants with the iron compounds of the mud.

Description Shrub or small tree up to 12 m tall; bole up to 60 cm in diameter, often crooked or branched from the base; bark rough and grooved, grey; crown rounded and open; branches densely and shortly greyish hairy. Leaves opposite to slightly alternate or sometimes in whorls of 3–4, simple; stipules absent; petiole 0.5–1.5(–3.5) cm long; blade elliptical, ovate or obovate, 9–18(–35) cm × 4–8(–20) cm, base rounded to attenuate, apex rounded to acute, margin entire, sometimes wavy, when young usually sticky above and densely grey pubescent below, lateral veins prominent, in 7–15 pairs. Inflorescence an axillary spike, up to 6 cm long. Flowers bisexual, regular, 4-merous, yellowish green, fragrant, sessile; receptacle cup-shaped, up to 4 mm wide; calyx lobes triangular; petals free, obovate to circular, 1–2.5 mm long; stamens 8; ovary inferior, style exserted. Fruit an ellipsoid, 4-winged samara 2.5–4 cm × 1.5–3 cm, glabrous or pubescent, often sticky near the centre, red to yellow-brown.



Combretum glutinosum – 1, flowering twig; 2, flower; 3, fruiting twig.
Redrawn and adapted by Achmad Satiri Nurhaman

Other botanical information *Combretum* is a very large genus, comprising about 250 species and distributed worldwide in the tropics and subtropics. About 140 species occur in tropical Africa. *Combretum schweinfurthii* Engl. & Diels, known from DR Congo, Sudan and Uganda, is possibly synonymous with *Combretum glutinosum*.

Several other *Combretum* species are used for dyeing in Africa. The major ones are: *Combretum erythrophyllum* (Burch.) Sond. from southern Africa of which the roots are used to dye textiles and baskets into rich dark brown colours, but its major use is as timber; *Combretum micranthum* G.Don from the western Sahel, used to dye red colours but more important as a medicinal plant; *Combretum nigricans* Lepr. ex Guill. & Perr. occurring from Senegal to Sudan and used to dye orange-red colours, but more important for its gum; *Combretum paniculatum* Vent., which is widespread all over tropical Africa and yields a yellow dye used in Kenya to dye green in combination with blue dyes, but more important as a medicinal plant.

Growth and development In the savanna zone *Combretum glutinosum* is evergreen, in the Sahel it loses its leaves for a few months during the dry season. Flowering is in the dry season after bush fires to which it is very resistant. Once established in an area, it easily forms dense stands.

Ecology *Combretum glutinosum* is found in savanna and open woodland with an annual rainfall of 200–900 mm. It is particularly resistant to arid conditions, surviving where grasses will not, and it recovers quickly from burning. It often grows gregariously on sandy and degraded soils.

Management *Combretum glutinosum* is not cultivated but often conserved when land is cleared. The tree coppices well. It is often infected by *Loranthaceae* plant parasites.

Harvesting The parts used for dyeing (leaves, bark, wood) are collected from shrubs and trees growing in the wild. In the Bélédougou region, fresh leaves collected just after the rainy season (in October) are considered best. Boys climb the trees and cut the ends of the young branches which are then tied together in bundles. These can be used fresh or are dried and stored for later use.

Handling after harvest According to traditional Mandé recipes, the fresh or dried leaves are boiled for about one hour in water to obtain a yellow liquid. The cloth is immersed in the bath when the liquid has cooled down. Then the cloth is dried in the sun and immersed in the bath again and this process is repeated several times until the desired basic yellow colour is obtained. While drying, the same side of the cloth is always exposed to the sun and turns a deeper yellow as a result of oxidation. When the cloth has been dyed and dried, it is stretched tautly and the parts that are planned to be dyed black are covered with liquid mud using a wooden stick ('kala') for straight lines and a special metal spatula ('binyèni') for drawing curves and filling spaces. When the mud is dry, it is shaken off and the cloth is washed well in water. The whole process of dyeing and applying mud is repeated up to 3 times to obtain a deep black ground. Finally the light-coloured designs are carefully covered with a bleaching paste. Sometimes the dye bath is prepared not by boiling, but by soaking fresh, previously pounded leaves for one or two days. This process takes longer, but saves fuel. The stem and root barks can also be pounded and steeped in water without heating to obtain orange shades for other types of textiles, in which case wood ash is usually added to the bath as a mordant.

Genetic resources *Combretum glutinosum* is widespread and not in danger of genetic erosion although the growing demand for bogolan textiles in recent years, plus other uses, are locally making the tree less common. Already in the 1990s women were complaining they had to walk ever further to gather the branches.

Prospects *Combretum glutinosum* will remain very important as a dye source in bogolan production. Growing interest in bogolan textiles will result in demand for greater and regular supplies of all the dye plants traditionally used. Taking also into account the demand due to the important medicinal properties of *Combretum glutinosum*, cultivation is recommended in the regions where it is used in big quantities, to prevent overexploitation and exhaustion of wild populations.

Major references Arbonnier, 2004; Burkill, 1985; Burkill, 2000; Cardon, 2003; Duponchel, 1997; Duponchel, 2004; Jossang, Pousset & Bodo, 1994; Liben, 1983; Muteba Luntumbue, 1998; Nacro & Millogo-Rasolodimbi, 1993.

Other references Adam, Echard & Lescot, 1972; Adjanohoun et al., 1985; Aubréville, 1944; Baba-Moussa, Akpagana & Bouchet, 1999; Bensaï, 1994a; Bensaï, 1994b; Berhaut, 1974; Buckingham et al., 1994–1995; Fortin, Lô & Maynart, 1990; Hindmarsh, 1982; Inngjerdongen et al., 2004; Kerharo & Adam, 1974; Kerharo & Bouquet, 1950; Mertz, Lykke & Reenberg, 2001; Miège, 1992; Neuwinger, 2000; Pousset, 2004; Taïta, 2000; van Wyk & Gericke, 2000.

Sources of illustration Aubréville, 1950; Malato-Beliz, 1977.

Authors M. Marquet & P.C.M. Jansen

COSMOS SULPHUREUS Cav.

Protologue Icon. 1: 56, t. 79 (1791).

Family Asteraceae (Compositae)

Chromosome number $2n = 24$

Synonyms *Bidens sulphurea* (Cav.) Sch.Bip. (1856).

Vernacular names Orange cosmos, yellow cosmos, sulphur cosmos (En). Cosmos soufré (Fr). Cosmos amarelo (Po).

Origin and geographic distribution *Cosmos sulphureus* originates from Central America (Mexico) and northern South America, where it is still found in the wild. It has been introduced as an ornamental in many countries all over the world, in tropical Africa e.g. in Senegal, Cameroon, Sudan, Tanzania, Malawi, Zambia, Zimbabwe, Mozambique, Réunion and Mauritius. Sometimes it has escaped from cultivation and behaves like a weed, e.g. in Tanzania, Malawi, Zimbabwe, the United States and Canada.

Uses The flower heads of *Cosmos sulphureus* and other *Cosmos*, *Bidens* and *Coreopsis* species have been major sources of yellow to orange dyes among the precolumbian civilizations of Central and South America. In southern Africa, they were adopted as a popular yellow dye by European settlers for domestic textile production and are still used by dyers using natural dyes as a hobby or for textile crafts, to dye wool bright yellow or orange. The flowers should first be boiled for about one hour before adding the mordanted wool to the cooled dye-bath and resuming boiling. Premordanting the fibres with different metallic salts gives various shades of lemon yellow to burnt orange. As a top-dye after a first red dyewood bath (e.g. of *Baphia nitida* Lodd.), it helps give a scarlet bloom to wool while on indigo-dyed wool, it produces greenish-brown shades. *Cosmos sulphureus* is commonly cultivated as an ornamental.

Properties The flower heads of most *Cosmos*, *Bidens*, and *Coreopsis* species contain flavonoid dyes of the chalcone and aurone groups. The specific flavonoids in *Cosmos* have not been fully elucidated, though the following have been found: luteolin, a group of flavonols having quercetin as their aglycone, and a group of chalcone glycosides. These are all good yellow colorants. The traditional medicinal applications in China of *Cosmos* and *Bidens* species have been confirmed by the fact that *Cosmos* and *Bidens* extracts are shown to inhibit bacteria, fungi, and viruses and to have potent anti-inflammatory effects in laboratory animal experiments with induced gastric ulcer, liver inflammation, or arthritis-type swelling.

Botany Annual herb up to 1.2(–2) m tall, with 4-angled, branched, pubescent to glabrescent stem. Leaves opposite, sessile or with clasping petiole up to 2 cm long; blade ovate in outline, up to 7 cm × 5 cm, very deeply dissected with ultimate segments narrowly oblong, c. 2.5 mm wide, apiculate, glabrous. Inflorescence a head c. 1.5 cm in diameter, solitary and terminal on stem and branches; peduncle up to 22 cm long (often much less); outer involucral bracts narrowly ovate, c. 12 mm long, acuminate, inner bracts with membranous margin. Ray flowers c. 10, corolla oblong-obovate, up to 3 cm long, apex 3-toothed, deep orange; disk flowers with narrowly funnel-shaped corolla, 5-lobed, c. 7 mm long, orange-yellow, subtended by scales c. 9 mm long. Fruit an achene c. 2 cm long, blackish, with a scabrid beak c. 7 mm long; pappus of 2 horizontally spreading awns c. 5 mm long.

Cosmos comprises about 25 species from tropical America; it belongs to the tribe *Heliantheae* and is related to the much larger genera *Bidens* and *Coreopsis*. *Cosmos sulphureus* as an ornamental comprises several cultivars.

Ecology Where *Cosmos sulphureus* has been found in the wild in Africa, it is a common roadside weed which does not spread into undisturbed localities. In southern Africa it flowers and fruits in March–May.

Management *Cosmos sulphureus* is propagated by seed. The flower heads of about two dozen plants are sufficient to dye 0.5 kg of wool or silk. They should be harvested when they open. They are soaked in water and the mixture is cooked until the flower heads become pale. The dye bath is yellowish in an acid solution (e.g. with vinegar) and reddish in a basic solution (e.g. with ammonia or washing soda). Alum and tartaric acid are often added as a mordant. The textile is simmered in the dye bath until the desired depth of colour is achieved, usually after about one hour.

Genetic resources and breeding *Cosmos sulphureus* is widespread in Central America and elsewhere it may behave as a weed. It does not seem to be in danger of genetic erosion. Breeding efforts are directed towards development of large-flowered ornamentals.

Prospects As a source of orange to yellow dyes, *Cosmos sulphureus* will remain only locally of importance in southern Africa and in Western countries.

Major references Hind, Jeffrey & Scott, 1993; Matlack, 2002; van Wyk & Gericke, 2000; Wild, 1967.

Other references Berhaut, 1974; Borghetti, 1998; Cardon, 2003; Dharmananda, undated.

Authors P.C.M. Jansen

CRATERISPERMUM LAURINUM (DC.) Benth.

Protologue Hook., Niger Fl.: 411 (1849).

Family Rubiaceae

Origin and geographic distribution *Craterispermum laurinum* is widespread in West Africa from Senegal to Togo.

Uses A brownish yellow dye is prepared from the bark and leaves of *Craterispermum laurinum* to dye cotton. In Sierra Leone the bark and leaves are sometimes pounded with grass and boiled to prepare a yellow dye. The bark is said to be sweet and edible. In Sierra Leone the stems are used for anchoring traps to catch animals. The stems split easily and are used in hut building to make woven networks of twigs to hold a mud cover or thatch. *Craterispermum laurinum* is used for live fencing as it is fire resistant and easily propagates from cuttings. The plant has many medicinal uses. A bark, leaf or root infusion or decoction is taken against cough, toothache, fever (including malaria), venereal diseases, high blood pressure and intestinal parasites. Powdered bark, leaves or roots are applied to wounds and sores.

Properties *Craterispermum laurinum* is a strong aluminium and a moderate silicon accumulator. Of these elements about 36 g/kg and 13 g/kg respectively were measured in the leaves. It is possible that an Al-Si complex is formed in the shoot tissues which may contribute to Al detoxification. Aluminium accumulating plants are used as mordants instead of alums in traditional dyeing techniques in different parts of the world. The yellow colours they often impart to textiles come from the combination of the organic mordant and dye components such as flavonoids. The recipe combining *Craterispermum laurinum* bark and leaves and an unspecified grass reported for Sierra Leone most probably implies such a combination of a mordant and yellow colouring compounds.

Botany Glabrous shrub or small tree up to 7 m tall, with twigs ridged at the nodes. Leaves opposite, simple and entire; stipules up to 6 mm long, connate at base, persistent; petiole up to 1.5 cm long; blade oblong-obovate, 10–20 cm × 4–9 cm, base attenuate, apex shortly pointed, leathery, yellow-green, pinnately veined with lateral veins in about 8 pairs. Inflorescence an axillary cyme situated slightly above leaf axil; peduncle up to 2 cm long. Flowers bisexual, regular, 5-merous, fragrant, shortly pedicellate, c. 6 mm long; calyx cup-shaped, truncate; corolla funnel-shaped, yellow-white, waxy, pubescent inside, soon falling; stamens inserted at the throat of the corolla, anthers exserted; ovary inferior, 2-celled, style filiform, stigma 2-lobed. Fruit a shortly stalked drupe c. 5 mm in diameter, blue-black, 1-seeded. Seed hemispherical.

Craterispermum comprises 15–20 species and is distributed in mainland Africa, Madagascar and the Seychelles. It is classified in subfamily *Rubioideae*, tribe *Craterispermeae*. *Craterispermum schweinfurthii* Hiern from central and eastern Africa has long been thought to be identical to *Craterispermum laurinum*, but differs in its shorter peduncles with more compact inflorescences, toothed calyx and sessile fruits.

In West Africa (Senegal to Nigeria), a yellow dye for raffia is extracted from the leaves of *Craterispermum caudatum* Hutch., a shrub or small tree of which the twigs are used as chewing sticks and for building huts.

Ecology *Craterispermum laurinum* is found in deciduous forest and along stream banks in savanna.

Management *Craterispermum laurinum* is occasionally cultivated as a fence. It propagates easily by cuttings.

Genetic resources and breeding *Craterispermum laurinum* is widespread and not in danger of genetic erosion.

Prospects *Craterispermum laurinum* as source of a dye will probably remain locally of minor importance. The combination of organic aluminium mordant and colorants in the same plant would make it a good source of fast dyes that could be combined with other vegetable dyes to obtain a wider range of colours, if programmes for the revival of the use of natural dyes were developing within the regions where it is widespread. Its medicinal properties need further investigation before its therapeutic value can be confirmed.

Major references Burkill, 1997; Irvine, 1961; Neuwinger, 2000.

Other references Abbiw, 1990; Aké Assi et al., 1985; Chifundera, 2001; Greenway, 1941; Hepper & Keay, 1963; Hiern, 1877; Jansen et al., 2003.

Authors P.C.M. Jansen

CRATERISPERMUM SCHWEINFURTHII Hiern

Protologue Oliv., Fl. trop. Afr. 3: 161 (1877).
Family Rubiaceae

Origin and geographic distribution *Craterispermum schweinfurthii* is found from Nigeria, throughout central and eastern Africa, and south to Angola, Zambia, Zimbabwe and Mozambique.

Uses The bark and leaves of *Craterispermum schweinfurthii* are a source of yellow and brown dyes used for dyeing cotton cloth. In DR Congo the dead wood, kept in moist conditions, becomes red and is used in the preparation of a red ointment ('nkula', also prepared from other sources) used to colour the face in traditional ceremonies. In Angola the species is valued as a live fence because of its resistance to fire and ease of cultivation. The fragrant flowers are a good bee forage. Twigs are used as toothpicks, toothbrushes and chewing sticks. The hard and tough wood is used for building poles, tool handles, sticks, firewood and charcoal. Applications in traditional medicine are numerous. The bark is chewed to cure coughs and whooping cough, a bark decoction is drunk in cases of stomach affections, fever, diarrhoea and used in vapour baths against rheumatism, oedema and sting-pain; powdered bark is applied to sores and wounds. Roots, bark and fruits are chewed and the juice taken against venereal diseases and as an aphrodisiac.

Properties No research on the dye or tannin content of this species appears to have been published, but the closely related *Craterispermum laurinum* (DC.) Benth. has been shown to be a strong aluminium accumulator. Such plants are used as mordants instead of alums in traditional dyeing techniques in different parts of the world and they often also contain colorants.

Botany Shrub or small to medium-sized tree up to 15 m tall, glabrous, with grey-white, warty bark. Leaves opposite, simple and entire; stipules triangular, situated between the petioles, up to 5 mm long; petiole 1–2 cm long; blade elliptical, oblong, obovate or oblanceolate, 5–17 cm × 2–8 cm, base cuneate, apex obtuse to acuminate, leathery, pinnately veined. Inflorescence a cyme situated slightly above leaf axil, compact and head-like; peduncle stout, up to 1 cm long. Flowers bisexual, regular, 5-merous, heterostylous, sweet-scented, sessile; calyx tubular to cup-shaped, up to 3 mm long, with small teeth; corolla salver- or funnel-shaped, white, tube 4–6 mm long, densely hairy inside, lobes oblong-ovate, 3–6 mm long; stamens inserted at the throat of the corolla, anthers with tips just exserted in long-styled flowers, completely exserted in short-styled flowers; ovary inferior, 2-celled, style filiform, c. 7 mm long in long-styled flowers, up to 4 mm long in short-styled flowers, stigma 2-lobed. Fruit a sessile drupe 5–6 mm in diameter, crowned with persistent calyx, 1-seeded. Seed bowl-shaped, 2–3 mm long, dark brown.

Craterispermum comprises 15–20 species and is distributed in mainland Africa, Madagascar and the Seychelles. It is classified in subfamily *Rubioideae*, tribe *Craterispermeae*. *Craterispermum schweinfurthii* has long been thought to be identical to *Craterispermum laurinum* (DC.) Benth. from West Africa, which differs in its longer peduncles with often branched inflorescences, truncate calyx and stalked fruits.

Craterispermum cerinanthum Hiern from West Africa is closely related or possibly identical to *Craterispermum schweinfurthii*; its 1 cm thick, white bark is said to be edible. The leaves of *Craterispermum dewevrei* De Wild. & T.Durand are used to cure wounds in Gabon.

Ecology *Craterispermum schweinfurthii* is found in evergreen fringing forest along water, swamp forest, drier evergreen forest and thickets, from sea-level up to 1500 m altitude.

Management *Craterispermum schweinfurthii* is easily propagated by cuttings; this is practised in Angola for live fencing.

Genetic resources and breeding *Craterispermum schweinfurthii* is widespread and not in danger of genetic erosion.

Prospects *Craterispermum schweinfurthii* will probably remain locally of minor importance as a source of a yellow, brown or red dye. Its chemical composition and medicinal properties need more investigation for a better evaluation.

Major references Burkill, 1997; Latham, 2004; Verdcourt, 1976.

Other references Aké Assi et al., 1985; Chifundera, 2001; Puff, 2003; Raponda-Walker & Sillans, 1961; Verdcourt, 1974; Verdcourt, 1989; Watt & Breyer-Brandwijk, 1962.

Authors P.C.M. Jansen

CREMASPORA TRIFLORA (Thonn.) K.Schum.

Protologue Engl. & Prantl, Nat. Pflanzenfam. 4(4): 88 (1891).

Family Rubiaceae

Synonyms *Cremaspora coffeoides* Hemsl. (1896).

Origin and geographic distribution *Cremaspora triflora* is widely distributed all over tropical Africa and Comoros, but it has not been reported from north-eastern tropical Africa (from Ethiopia to Somalia) or south-western Africa (Namibia to Botswana).

Uses The unripe and ripe fruits of *Cremaspora triflora* produce a blue-black dye, used in various parts of Africa as a cosmetic to colour the face and body. The ripe fruit is said to be edible. The crushed seed produces a deep black dye, also used to colour body and face and in DR Congo to dye barkcloth made from *Ficus thonningii* Blume. *Cremaspora triflora* is planted as an ornamental somewhat resembling a coffee shrub, bearing white sweet-scented flowers. The wood is used in construction as poles and also makes good firewood. In Côte d'Ivoire the bark is used to strengthen fermented drinks, and to alleviate toothache by putting a piece of bark in a diseased tooth and by washing the mouth with a bark decoction. In Tanzania a root extract is used against rheumatism. A decoction of the plant is drunk against swellings, intestinal parasites and as a diuretic.

Properties There is no information on the dye components of the fruits and seeds. Alkaloids are present in leaf and bark The wood of *Cremaspora triflora* is yellowish and hard.

Botany Shrub, liana or small tree up to 9 m tall, usually much branched; stem glabrescent to densely hairy. Leaves opposite, simple and entire; stipules triangular, up to 7 mm long; petiole short; blade oblong, elliptical or oblanceolate, 2–18 cm × 0.5–9 cm, base rounded to cuneate, apex acuminate, glabrous above, glabrous to pubescent beneath; leaves subtending lateral branches mostly rounded to kidney-shaped, 3–4 cm in diameter. Inflorescence a dense axillary fascicle 2–3 cm wide. Flowers bisexual, regular, 5-merous, strongly sweet-scented, sessile; calyx tubular, lobes up to 2 mm long; corolla tubular, white or yellowish, tube 3–6(–10) mm long, lobes 3–7 mm long; stamens inserted at the mouth of the tube, filaments very short; ovary inferior, 2-celled, style up to 16 mm long, at apex 2-lobed with stigmatic surface on inside of the lobes. Fruit an ovoid or ellipsoid berry, 7–15 mm × 5–7(–12) mm, red, glabrous to densely hairy, crowned with persistent calyx, usually 2-seeded. Seeds compressed half-ovoid, 5–7 mm × 3–5.5 mm × 2–3.5 mm, testa finely transversely wrinkled.

Cremaspora comprises 3–4 species and is confined to tropical Africa, Comoros and Madagascar. *Cremaspora triflora* is very variable and three subspecies have been distinguished, mainly based on differences in form and size of leaves, calyx lobes and fruits: the widespread subsp. *triflora*, subsp. *confluens* (K.Schum.) Verdc. from Kenya, Tanzania and Malawi, and subsp. *comorensis* (Baill.) Verdc. from Comoros.

Ecology *Cremaspora triflora* is found in evergreen forest, fringing forest, bushland and thicket from sea-level up to 2000 m altitude.

Genetic resources and breeding *Cremaspora triflora* is widespread and is not in danger of genetic erosion.

Prospects *Cremaspora triflora* as source of a dye will remain only locally of some importance. Its medicinal and ornamental properties need more investigation.

Major references Bridson & Verdcourt, 1988; Burkill, 1997; Irvine, 1961.

Other references Adjanohoun et al., 1989; Beentje, 1994; Hepper & Keay, 1963; Kokwaro, 1993; Neuwinger, 2000; Raponda-Walker & Sillans, 1961; Staner, 1936; Verdcourt, 1980.

Authors P.C.M. Jansen

CROCUS SATIVUS L.

Protologue Sp. pl. 1: 36 (1753).

Family Iridaceae

Chromosome number $2n = 24$

Vernacular names Saffron, crocus (En). Safran, safran vrai (Fr). Açafrão, açaflor, croco (Po).

Origin and geographic distribution *Crocus sativus* is known only as a cultivated plant. It probably originated in Greece and western Asia, where some wild species occur which are possibly related. In very ancient times it was spread eastward to Kashmir in India. Later its cultivation spread to European temperate countries, western Asia, northern India and China. In tropical Africa saffron is rarely cultivated, but there are reports from the Hoggar area in southern Algeria and northern Mali. Its bulbs are imported occasionally, e.g. they are for sale on markets in Mauritius.

Uses The dried upper part of the yellow style with 3 red stigmas attached, picked from the flowers of *Crocus sativus*, is the saffron of commerce, which is used mainly to colour and flavour foods. Saffron was also applied in textile dyeing, but only rarely and only for precious silks and special uses (e.g. women's underwear).

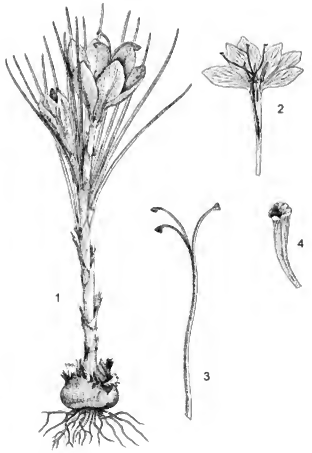
Medicinally, saffron is considered an anodyne, antispasmodic, aphrodisiac, diaphoretic, emmenagogue, expectorant and sedative, but the many therapeutic properties of saffron are disputed. In traditional medicine it is used against scarlet fever, smallpox, colds, insomnia, depression, asthma and tumours. Saffron is an important ingredient in Ayurvedic and other systems of medicine in India. In Mauritius a paste of the bulb is applied to skin affections. *Crocus sativus* is widely planted as an ornamental in gardens.

Production and international trade *Crocus sativus* is by far the world's most expensive food-dye and spice. Spain has been the main producer, accounting for 90% of the world's production, but a large proportion of the export of Spain originates from plants actually grown in Iran. Other exporting countries are India (Kashmir), France, Italy and Algeria. The annual production in India at the beginning of the 1980s was estimated at 9–10 t. The international market price in that period was about US$ 1000 per kg.

Properties The chief colorants of *Crocus sativus* are the yellowish-red carotenoid glycoside crocin and the bitter glycoside picrocrocin. On hydrolysis crocin yields the sugar gentiobiose and crocetin. Saffron also contains the pleasantly smelling safranal, which develops during the drying process by enzymatic or thermal dissociation of picrocrocin.

In animal tests crocetin improved oxygenation in cases of haemorrhage, showed positive results in the treatment of atherosclerosis and arthritis, and inhibited the development of chemically induced skin tumours. In a pilot double-blind randomized clinical trial in Iran, saffron was found to be effective in a way similar to imipramine in the treatment of mild to moderate depression.

Botany Small stemless perennial herb up to 30 cm tall, having a more or less globular subterranean corm 3–5 cm in diameter, surrounded by a finely reticulate-fibrous tunic and rooting at base. Leaves linear, 1.5–2(–3) mm broad, with a white median stripe above, keeled below. Flowers 1–3, bisexual, regular, each on a short subterranean pedicel, subtended by membranous bracts; perianth with a long cylindrical tube and 6 segments 2.5–5 cm × 1–2 cm, deep lilac-purple or mauve coloured with darker veins, white or lilac in the throat; stamens 3; ovary inferior, style divided into 3 brilliant orange-red stigmas 2.5–3.5 cm long.



Crocus sativus – 1, plant habit; 2, opened flower; 3, style and stigmas; 4, stigma.
Source: PROSEA

Crocus comprises about 80 species and occurs from Europe to central Asia. *Crocus sativus* is a sterile triploid which reproduces only vegetatively. The corms reproduce annually, giving rise to new young cormlets. Being very expensive saffron is often adulterated in a variety of ways. Not only is very impure saffron consisting of floral parts other than stigmas sold, but parts of other plant species with dyeing properties are also offered under the name 'saffron', such as powdered rhizomes of turmeric (*Curcuma longa* L.), and flowers of safflower (*Carthamus tinctorius* L.). The dyeing substances from these plants can be used in the same way as true saffron, and are much cheaper. In East and southern tropical Africa the yellow dye obtained from the flowers of *Crocosmia aurea* (Pappe ex Hook.) Planch. can be used as a substitute for saffron. *Crocosmia aurea* is also used in traditional medicine, e.g. leaf sap and a decoction of the corm is drunk to treat malaria, and a root decoction is drunk to treat arthritic rheumatism, for which purpose the ash of the plant with *Ricinus* oil is also embrocated into scarifications.

Ecology *Crocus sativus* thrives best in temperate and fairly dry climates. In the areas of Spain where saffron is cultivated, annual rainfall only rarely exceeds 400 mm. Two periods of heavy rainfall are adequate for good yields, one in spring for the production of new corms and a second at the end of summer to promote flowering. *Crocus sativus* flowers in autumn. Frosts or rains during flowering are harmful and can damage the crop.

Management Propagation is by means of corms. Cultural practices vary for the different producing countries. Once planted, corms may remain in the field for 3–12 years, but sometimes saffron is grown as an annual crop. The flowering and harvesting season lasts for about 4 weeks. The flowers must be picked in the early morning, and the stigmas should be removed on the same day. The 3 stigmas are dried, along with about 5 cm of the style attached, and constitute the pure saffron of commerce. An average yield is about 1 million flowers per ha, which in turn produces 10 kg dried saffron. Fire-dried saffron is more valuable than sun-dried. Saffron is marketed both as a powder and as the much less dense 'hay saffron', i.e. loose stigmas. Quality is maintained by storage at low humidity.

Genetic resources and breeding *Crocus sativus* has been shown to be genetically homogeneous throughout its region of cultivation, from Spain to China, as a result of continued vegetative propagation of a single clone.

Prospects As it is not suited to tropical and high-rainfall climates, *Crocus sativus* does not have good prospects in tropical Africa. However, as saffron is valued in parts of the region and as products from other plant resources are often confused with true saffron, it seemed useful to give some attention to this species.

Major references Basker & Negbi, 1983; Burkill, 1994; Wessel-Riemens, 1991.

Other references Adjanohoun et al., 1983b; Akhondzadeh et al., 2004; Giaccio, 2004; Sampathu, Shivashankar & Lewis, 1984.

Sources of illustration Wessel-Riemens, 1991.

Authors P.C.M. Jansen

Based on PROSEA 3: Dye and tannin-producing plants.

CRYPTOLEPIS SANGUINOLENTA (Lindl.) Schltr.

Protologue Westafr. Kautschuk-Exped. 308 (1900).

Family Asclepiadaceae (APG: Apocynaceae)

Origin and geographic distribution *Cryptolepis sanguinolenta* is found from Senegal to Nigeria, and has also been recorded from Cameroon, Central African Republic, Congo, DR Congo, Uganda and Angola.

Uses The roots of *Cryptolepis sanguinolenta* are collected from the wild and locally sold on markets in West Africa. They are a source of a yellow dye, which is used for dyeing leather, e.g. in Nigeria for tanned goat skins. The roots are crushed and ground in a wooden mortar, a little hot water is added and the mixture is stirred. It has a dull yellow colour and should be used immediately. The tanned goat skin surface is first treated with some groundnut oil and subsequently dipped in the dye bath, the extract being well rubbed into the surface. After a few minutes a piece of tamarind (*Tamarindus indica* L.) fruit paste is added. This paste is prepared from seeds and fruit pulp soaked in cold water and gradually warmed up until a pulpy mass develops. This new mixture is also rubbed in. The skin is exposed to the air for 2–3 minutes and after that again rubbed in with the mixture for about 5 minutes, wiped clean and hung up to dry. The effect of the tamarind fruit paste is to purify the colour; it removes the red tint that would result from the addition of alkali in the dye bath.

In Burkina Faso the leaves are used as a vegetable. In traditional medicine extracts of *Cryptolepis sanguinolenta* (usually roots) are used to treat fever, hepatitis (Guinea Bissau), malaria (Ghana), urinary and upper respiratory tract infections (Nigeria), colic and stomach complaints (Senegal, Nigeria, DR Congo, Uganda), wounds, hernia (Uganda), snakebites (Uganda), rheumatism (Senegal, Nigeria), and as a tonic (Senegal, Nigeria).

Properties The leaves and roots of *Cryptolepis sanguinolenta* are rich in bioactive indole alkaloids such as cryptolepine, the major constituent of the roots and the first alkaloid isolated from the plant. From the roots 11 other structurally related alkaloids have been isolated, such as hydroxycryptolepine, isocryptolepine, cryptospirolepine and quindoline. But recent research has shown that in an aqueous extract of the roots only cryptolepine was detected and thus constitutes the main or only source of yellow colorant in the dye baths. Other yellow alkaloid dyes such as berberin from *Berberis* and *Mahonia* species have had historical importance in Asia, Europe and America. All the alkaloid compounds in *Cryptolepis sanguinolenta* also have medicinal properties, those with weakly basic characteristics showing a strong antiplasmodal activity against *Plasmodium falciparum* (causing malaria disease). Cryptolepine, the most extensively investigated alkaloid of the plant, also has antibacterial, hypothermic, hypotensive, renal vasodilator, antipyretic, anti-inflammatory, antithrombotic and anti-hyperglycemic activities.

Botany Twining and scrambling shrub with thin branches up to 8 m long, containing yellow-orange juice becoming red upon drying. Leaves opposite, simple, glabrous; stipules absent; petiole 1–1.5 cm long; blade elliptical to ovate, 2.5–10 cm × 1–6 cm, base rounded to cuneate, apex acuminate, margin entire. Inflorescence an axillary panicle 5–8 cm long, with few, laxly spaced flowers. Flowers bisexual, regular, 5-merous, c. 1.5 cm long, greenish yellow; pedicel 0.5–1.5 cm long; corolla with tube c. 5 mm long, lobes arranged star-like, lanceolate, c. 12 mm long, contorted to the left in bud. Fruit a pair of spreading follicles, each narrowly cylindrical and up to 18 cm × 0.5 cm. Seeds c. 12 mm long, bearing a coma of long silky hairs.

Cryptolepis comprises about 20 species (10 in Africa, 2 in Madagascar, 4 in Asia, 3 in Papua New Guinea and 1 in Australia) and has often been classified in a separate family: *Periplocaceae*. The distribution and chemical composition of *Cryptolepis sanguinolenta* is quite different from the other African *Cryptolepis* species. The latter are confined to the east coast. The leaves of most *Cryptolepis* species contain phenolic compounds, but these are absent in the leaves of *Cryptolepis sanguinolenta*.

Ecology *Cryptolepis sanguinolenta* is often found in gallery forest, usually near water.

Genetic resources and breeding *Cryptolepis sanguinolenta* is widespread and does not seem to be in danger of genetic erosion.

Prospects *Cryptolepis sanguinolenta* will remain locally important as a source of yellow dye. Its medicinal activities are promising and certainly deserve more attention.

Major references Berhaut, 1971; Bullock, 1955; Bullock, 1963; Burkill, 1997; Dalziel, 1926.

Other references Bierer et al., 1998; Brown, 1902–1904; Grellier et al., 1996; Kerharo & Adam, 1974; Mertz, Lykke & Reenberg, 2001; Paulo et al., 2000; Paulo & Houghton, 2003; Silva et al., 1996; Tabuti, Lye & Dhillion, 2003; Watt & Breyer-Brandwijk, 1962.

Authors P.C.M. Jansen

CURCUMA LONGA L.

Protologue Sp. pl. 1: 2 (1753).

Family Zingiberaceae

Chromosome number $2n = 63$

Synonyms *Curcuma domestica* Valeton (1918).

Vernacular names Turmeric (En). Curcuma, safran pays, safran des Indes (Fr). Curcuma, rizoma dos Índios, açafroeira da Índia, terra merita (Po). Mmanjano (Sw).

Origin and geographic distribution The origin of *Curcuma longa* is not certain but it is thought to originate from southern Asia, most probably from India. *Curcuma longa* does not occur in a true wild state, although in some regions it appears to have become naturalized. It is a sterile triploid and is thought to have arisen by continued selection and vegetative propagation of a hybrid between the diploid wild turmeric (*Curcuma aromatica* Salisb., native to India, Sri Lanka and the eastern Himalayas) and another closely related tetraploid *Curcuma* species.

India is considered a centre of domestication and *Curcuma longa* has been grown there since time immemorial. It reached China before the 7th century, East Africa in the 8th century and West Africa in the 13th century. It was introduced into Jamaica in the 18th century. At present turmeric is widely cultivated throughout the tropics, but commercial production is concentrated in India and South-East Asia. In Africa it is cultivated in home gardens in many countries and is for sale in numerous markets.

Uses *Curcuma longa* is cultivated for its rhizome, primarily as a dye source, secondly as a culinary spice. In West Africa its major use is as a dye to colour products such as tanned leather, cotton cloth, thread and palm fibres a golden-yellow. Rhizomes are also used in Africa and Asia as a cosmetic for body and face. They are an auspicious article in all religious observances in Hindu households, and have many other uses in daily life in connection with birth, marriage, death, and in agriculture. In Asia turmeric is widely used as an important constituent of curry powder (contains up to 25% turmeric). In Western countries, ground turmeric rhizome is widely used in the food industry, in particular as a colouring agent (E 100 in the European Union) in processed foods and sauces. It is also applied as a colouring agent in pharmaceuticals, confectionery and textile dyes, and is a cheaper substitute for the true saffron (*Crocus sativus* L.).

Young shoots and young rhizomes can be eaten fresh as a spicy vegetable. Turmeric oil and oleoresin find similar applications as the ground spice. In the United States the regulatory status 'generally recognized as safe' has been accorded to turmeric oil (GRAS 3085) and turmeric oleoresin (GRAS 3087). The maximum permitted level of turmeric oil in fragrances is 1%, but it is now rarely used.

Turmeric rhizomes are part of numerous traditional compound medicines used as stomachic, stimulant and blood purifier, and to treat liver complaints, biliousness and jaundice. Mixed with warm milk they are used to cure common cold, bronchitis and asthma. Juice from fresh rhizomes is applied against many skin infections, while a decoction is effective against eye infections. Research since the 1970s has found promising pharmaceutical activity against cancer, dermatitis, AIDS, inflammation, high cholesterol levels and dyspeptic conditions. Turmeric also has insecticidal, fungicidal and nematicidal properties. In Madagascar ground rhizomes are mixed with grains to protect them from storage pests. The leaves are used in preparing a special medicinal bread in Nepal and India.

Production and international trade *Curcuma longa* enters into international trade mainly in the form of dried whole rhizomes. Trade in ground turmeric is less important than it used to be. India is the largest producer, with 400,000 t from 130,000 ha and dominates the international trade which is estimated at 20,000 t annually. Other producers in Asia include Bangladesh, Pakistan, Sri Lanka, Taiwan, China, Myanmar and Indonesia. It is also cultivated in the Caribbean, and in Central and South America, with Jamaica, Haiti and Peru being the most important producing countries. All Asian producers are heavy consumers as well and some are even net importers, whereas non-Asian countries export most of their production. Trade in turmeric from Asian countries is mainly routed through Singapore. Leading importers are Iran, Sri Lanka, most of the Middle East and North African countries. Taiwan is the main supplier of Japan, whereas Jamaican turmeric goes mainly to the North American market. In the 1980s and 1990s the United States imported about 1850 t turmeric annually, with a value of about US$ 2 million.

Properties Per 100 g edible portion ground turmeric contains approximately: water 11.4 g, energy 1481 kJ (354 kcal), protein 7.8 g, fat 9.9 g, carbohydrate 64.9 g, dietary fibre 21.1 g, Ca 183 mg, Mg 193 mg, P 268 mg, Fe 41.4 mg, Zn 4.4 mg, vitamin A 0.0 IU, thiamin 0.15 mg, riboflavin 0.23 mg, niacin 5.14 mg, folate 39 µg, ascorbic acid 25.9 mg (USDA, 2004). On steam distillation the rhizomes yield 2–7% essential oil, which is orange-red and slightly fluorescent. Its major constituents are the sesquiterpene zingiberene 25% and the ketonic derivatives turmerone 35% and ar-turmerone 12%. Extraction of the rhizome with ethyl alcohol, acetone or methylene chloride yields 6–10% oleoresin, which contains 35–45% curcumin and its derivatives demethoxycurcumin and bis-demethoxycurcumin, collectively known as curcuminoids. These compounds give turmeric the characteristic yellow-orange colour (Natural Yellow No 3 of the Colour Index), the essential oil gives it the typical aroma and flavour. The contents of the rhizome are very variable and depend on the site of cultivation, type of cultivar, moment of harvest, method of processing and method of analysis.

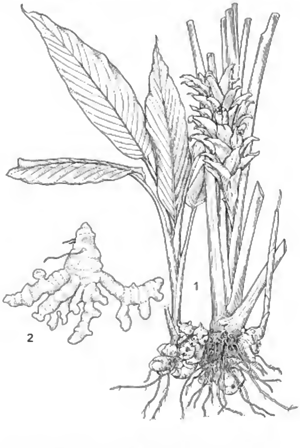
Turmeric is recognized in the dyeing industry as one of the 'direct colours', capable of dyeing cotton without a mordant. However, as the pigment is extremely sensitive to light, it easily discolours, and when applied to cotton, wool or silk it is usually used in a weak solution of acetic acid or alum. Alkali in the dye bath would impart a reddish hue. In West Africa tamarind pulp is added to the turmeric dye bath, probably to purify the colour and to remove any red tint.

The essential oil of turmeric is composed mainly of oxygenated monoterpenes, with smaller quantities of sesquiterpene hydrocarbons and monoterpene hydrocarbons. The relative contribution of individual components to the aroma and flavour is not well known. The aroma of steam-distilled essential oil differs in character from that of the spice and this is believed to arise from artefact formation during the distillation process. A monograph on the physiological properties of turmeric oil has been published by the Research Institute for Fragrance Materials (RIFM).

Curry powder usually contains, in addition to turmeric, spices such as coriander, cumin, cinnamon, cardamom, fenugreek, chilli, nutmeg, clove, ginger, pepper and dill. The proportions of the different ingredients vary with the sort of food being curried, but turmeric and coriander are usually most abundant. Modern medicinal research (in tests with animals such as rats and mice) has revealed that curcumin and its allies possess anti-oxidant, anti-inflammatory and anti-carcinogenic properties. Turmeric can lower lipid peroxidation by maintaining the activities of anti-oxidant enzymes like superoxide dismutase, catalase and glutathione peroxidase at higher levels. These enzymes play an important role in the regulation of lipid peroxidation (curcumin was effective in acute as well as chronic models of inflammation). The lipid peroxidation has a main role in inflammations, heart diseases and cancer. In tests turmeric has also shown antiprotozoal, nematicidal, antibacterial, antivenom, antiviral and antitumour activities. In clinical studies promising results were obtained by oral administration of turmeric to patients with rheumatoid arthritis, respiratory diseases, peptic ulcers and dyspepsia.

Adulterations and substitutes The early history of *Curcuma longa* is bound up with that of saffron, for which it is a much cheaper substitute. In India adulteration of turmeric itself is a serious problem in local markets and ground turmeric is more vulnerable to such practice. It is not uncommon to find turmeric powder locally adulterated with lead chromate, yellow earth, sand, or cheap talc. However, in the international market, concern over possible adulteration relates mainly to the mixing of related *Curcuma* species containing curcuminoid pigments into turmeric rhizome material. There are three other curcumin-containing species that are significant with regard to adulteration: *Curcuma xanthorrhiza* Roxb., *Curcuma aromatica* Salisb. (wild turmeric or yellow zedoary) and *Curcuma zedoaria* (Christm.) Roscoe (zedoary). In the producing countries of Asia these three species are variously used as a source of starch, dyes and in folk medicine and as a substitute for true turmeric (not as a spice but in other applications). Identifying these species by microscopy of ground material is often difficult, particularly if the starch grains and oleoresin cells have been destroyed by boiling. Adulteration of *Curcuma longa* by *Curcuma aromatica* or *Curcuma zedoaria* can be detected from the presence of camphor and camphene, which occur as minor components in the essential oil of the latter two species.

Description Perennial, erect, strongly tillering herb (often cultivated as an annual), up to 1(–1.5) m tall; rhizome a fleshy complex with an ellipsoid primary tuber c. 5 cm × 2.5 cm, ringed with the bases of old scale leaves and when mature bearing numerous straight or slightly curved, cylindrical, branched, lateral rhizomes (called fingers) 5–10 cm × 1–1.5 cm, the whole forming a dense clump; rhizomes inside and outside bright orange-yellow, young tips white, with a spicy smell when bruised; roots filiform, tough. Leaves alternate, distichous, simple, with sheaths forming a short pseudostem; petiole 0.5–10 cm long, broadly furrowed and narrowly winged; blade oblong-lanceolate, 7–70 cm × 3–18 cm, base cuneate to rounded, apex acute or acuminate, above dark green, below very pale green, densely studded with pellucid dots. Inflorescence a terminal spike up to 20 cm long, erect, appearing between the leaf sheaths; peduncle 3–20 cm long, densely hairy, covered by bladeless sheaths or scales; bracts elliptical-lanceolate, 5–7.5 cm × 2.5 cm, densely hairy, pale green to white. Flowers in pairs in axils of bracts, bisexual, zygomorphic, 5–6 cm long, opening one at a time; calyx tubular, short, with 3 unequal



Curcuma longa – 1, plant habit; 2, rhizome. Source: PROSEA teeth; corolla tubular at base, upper half much widened and with 3 unequal lobes, white; labellum (central staminode) orbicular to obovate, 12–17 mm in diameter, with 2 small lateral lobes and a large emarginate central lobe, white with a yellow central streak, lateral staminodes 2, elliptical-oblong, c. 1 cm × 6 mm, creamy-white, functional stamen 1, for larger part connate with staminodes, 5–6 mm × 3 mm, anther with a broad, curved large spur at base; ovary inferior, 3-celled, with 2 erect glands at top, style slender, passing between and held by the anther thecae, stigma expanded. Fruit never produced.

Other botanical information *Curcuma* comprises about 50 species and is native from India to northern Australia; several species have been introduced in other tropical regions. The identity of *Curcuma longa* as a species needs better investigation. In Asia a group of closely related species is now distinguished solely by the different colours of the bracts, corolla, leaves or rhizomes, but in fact they form a single complex species around *Curcuma longa*. In some countries, especially India, several not officially recorded cultivars are distinguished by the names of the localities in which they are grown, some types being preferred for spice use (e.g. Madras type with up to 3.5% curcuminoid pigments), others for dyeing (e.g. Alleppey type, with up to 6.5% curcuminoid pigments). A thorough revision is needed to establish reliable cultivar groups and cultivars.

Growth and development During establishment, sprouting of sets of turmeric is completed in 2–4 weeks; this is followed by a period of active vegetative growth. Flowering and rhizome development start about 5 months after planting. Active rhizome development continues for about 7–10 months, depending upon cultivar and climatic conditions; then the lower leaves turn yellow and the crop is ready for lifting.

Ecology Turmeric requires warm and moist conditions. It can be cultivated in most areas of the tropics and subtropics provided rainfall is adequate (1000–2000 mm) or facilities for irrigation are available. A well-distributed rainfall of 1200–1400 mm in 100–120 days is optimal. Cultivation has been extended into areas with over 2000 mm rainfall. Turmeric is grown up to altitudes of 1200 m in the Himalayan foothills but it performs better at altitudes of 450–900 m. Optimum temperature ranges are 30–35°C during sprouting, 25–30°C during tillering, 20–25°C during rhizome initiation and 18–20°C during the bulking stage. Turmeric is grown in various soil types, but prefers well-drained, loose and friable, fertile loam or clay loam, with good organic matter status, and a pH of 5–7.5. It cannot stand waterlogging or alkaline soils. Gravelly, stony and heavy soils are unsuitable for the development of rhizomes. As a shade-loving plant it does well in partial shade and can be cropped under fruit trees.

Propagation and planting Turmeric is propagated vegetatively by rhizomes. Mother rhizomes, whole or cut into pieces, and daughter rhizomes (fingers) are generally used. As seed material mother rhizomes are better than daughter rhizomes. However, it has also been stated that large daughter rhizomes sprout better and produce higher yields than mother rhizomes. Finger rhizomes store better, are more tolerant of wet soil conditions and can be planted at a lower density. It is necessary to store rhizomes for 2–3 months from harvest to planting. This may be done by spreading them thinly under a covering of turmeric leaves or storing them in heaps under a layer of straw and soil.

The field should be well prepared by ploughing or digging and turning over to a depth of about 30 cm, to provide a good tilth. Large quantities of organic manure (farmyard manure, oilseed cake, green leaves) are usually applied. The optimum is reported to be about 25 t/ha of cattle manure or compost and 65 kg/ha of N through oilseed cake. Turmeric is generally planted by one of two methods: the flat-bed method or the ridge and furrow method. The flat-bed method is generally better, but in sites with excessive or deficient moisture the ridge and furrow method is superior, facilitating drainage and irrigation. Ridges should be 20–25 cm high and 45–50 cm wide and the rhizomes planted at a distance of 30–40 cm, at a depth of 7.5 cm. A spacing of 25 cm × 25 cm for the flat-bed method is optimal. However, good results have been obtained at spacings of 30 cm × 15 cm and 15 cm × 15 cm. If turmeric is intercropped, spacing is adjusted accordingly. Planting time depends on cultivar, planting material and agroclimatic conditions. Rapid multiplication of turmeric has been reported using in vitro culture of young vegetative buds excised from sprouting rhizomes. Plantlet formation occurred throughout the year without exhibiting the usual dormancy period of field-grown plants.

Management After planting it is beneficial to mulch with locally available leaves, straw or sugarcane trash. This practice improves rhizome establishment, suppresses weeds and increases plant height and rhizome yield. It is recommended to apply a mulch of green leaves twice at a rate of 15 t/ha, at planting and 60 days after planting. After-planting care consists of weeding, irrigation, protection against diseases and pests, and application of fertilizers. Early weeding may be avoided by the use of 2,4-D as a pre-emergence herbicide. Three to four hoeings followed by weeding at regular intervals are desirable. Earthing-up may be necessary about 8 weeks after planting.

A good soaking of the field at planting is beneficial, followed by a weekly irrigation until sprouting is completed, after which less frequent watering is required. Turmeric, being an exhaustive crop, requires heavy manuring for high yield. Under rainfed conditions the application of ammonium sulphate at a rate of 100 kg/ha has been reported to increase yield by nearly 100%. Response to phosphorus at a rate of up to 175 kg/ha and in combination with other nutrients has also been reported. Application of potassium significantly increases plant height, and the number of tillers, leaves, and mother and daughter rhizomes. Among micronutrients, responses to iron and zinc have been reported (50 kg each of $FeSO_4$ and $ZnSO_4$). However, recommendations of fertilizer application differ widely from place to place.

Diseases and pests Leaf spot or leaf blotch, and rhizome rot are the most important diseases of turmeric. Leaf spot or leaf blotch, caused by *Taphrina maculans*, is characterized by the appearance of spots on both surfaces of the leaves, 1–2 mm in diameter, coalescing freely. Infected leaves are distorted, have a reddish brown appearance and soon become yellow. The disease can be controlled reasonably by Bordeaux mixture, ethion and zineb. Cultivars resistant to the disease are available. Another leaf spot disease is caused by *Colletotrichum capsici*, provoking spots of variable size, enlarging to 4–5 cm × 3 cm and frequently coalescing over most of the leaf, which then dries up. In very severe infestation most leaves dry up, presenting a scorched appearance, resulting in yield losses of more than 50%. The disease can be checked by spraying Bordeaux mixture once before symptoms appear. Captan and zineb, applied at monthly intervals, control the disease adequately. Planting materials should be selected from disease-free areas and treated with an authorized fungicide before planting. Excess shade and intercropping favour the disease.

Rhizome rot caused by *Pythium aphanidermatum* shows progressive drying-up of the leaves of infected plants. The base of the aerial shoots shows water-soaked soft lesions. As the disease progresses infection gradually passes to the rhizomes, which begin to rot and become soft. The bright orange colour of the rhizomes changes into brown. The disease may be confined to a few isolated plants or may occur in patches. In severe attacks the yield is considerably reduced. One of the effective control methods is eradication and burning of infected plants. In serious cases it may be advisable to disinfect the soil with an authorized fungicide (e.g. metalaxyl and mancozeb). Treating the planting material with a fungicide helps preventing the disease. Some cultivars (e.g. 'Suvarna' in India) have shown field tolerance.

Pests of turmeric include shoot borers, leaf-eating insects, sucking insects and nematodes. In Asia caterpillars of the shoot borer *Conogethes punctiferalis* (synonym: *Dichocrocis punctiferalis*) attack the central shoot, causing it to die ('dead heart'). Monthly spraying with malathion controls the insect. In India the hesperiid caterpillar *Udaspes folus* ('grass demon') is also a serious foliage feeding insect. It is recommended to spray carbaryl, dimethoate or phosphamidon for its control. In Africa and the South Pacific the scale insect *Aspidiella hartii* is a sucking insect infesting rhizomes while still in the field. It multiplies on fresh rhizomes being kept for seed. The infested rhizomes ultimately desiccate. Control is achieved by dipping the seed rhizomes in phosalone, monocrotophos or quinalphos. Two hymenopteran parasites, *Physcus* sp. and *Adelencyrtus moderatus*, attack this pest. In Asia the tinged bug, *Stephanitis typica*, causes leaf discolouration by sucking the sap. Thrips also suck the leaves, which then roll up, turn pale and gradually dry up. The nematodes recorded in turmeric include root-knot nematode (*Meloidogyne incognita*) and burrowing nematode (*Radopholus similis*).

Harvesting Turmeric is ready for harvest 7–10(–12) months after planting, when the lower leaves turn yellow. Harvesting is done by digging. Care should be taken not to damage the rhizomes and to ensure that the whole clump is lifted together with the dry plant. Leafy tops are then cut off, roots and adhering earth removed, and rhizomes are well washed. The finger rhizomes are separated from the mother rhizome. A few rhizomes may be used fresh and, except for those that are required for replanting, the remainder are processed.

Yield The average yield of fresh turmeric rhizomes is 17–23 t/ha if the crop is irrigated, and 6.5–9 t/ha under rainfed conditions. However, yields depend largely upon the cultivar. Some cultivars are capable of yielding 30–35 t/ha of fresh turmeric rhizomes.

Handling after harvest To develop the attractive yellow colour and the characteristic aroma, the cleaned rhizomes are cooked in boiling water for 1 hour under slightly alkaline conditions. The cooked material is dried in the sun for 6–8 days. Hot-air dryers are also used. Dried rhizomes are polished to smooth their exterior and also to slightly improve the colour. The polishing can be done in a simple rotating cylindrical galvanized iron drum turned by hand, or in other types of equipment. A small quantity of turmeric powder sprinkled in during polishing gives the product a good appearance.

In its simplest form, the method used to dye leather in Nigeria is merely to make a paste of the pulverized turmeric rhizome with water, and rub it well into the tanned hide after lightly oiling the surface. The hide is then washed with a weak mixture of lime juice and water, and dried. In the north-eastern Province of Bornu, the hides to be dyed are not oiled, and the dyestuff is prepared for use by mixing with water and a mineral containing sodium (bi)carbonate. This mixture turns the hides almost red, but the colour is purified to yellow by washing with lime juice and water. In Sokoto in north-western Nigeria, cotton cloth is dyed by dipping it into the dye paste and rubbing the paste well into the cloth with the hands. After a few minutes a piece of tamarind paste is added and the mixture again rubbed in (the tamarind paste is prepared from entire pods which are soaked in cold water and then gradually warmed in a vessel over the fire to a temperature that can still be easily handheld; the soft pulpy mass is then wrapped in leaves and kept for use). Then the cloth is taken out, shaken and exposed to the air for 2–3 minutes while wiping off any adhering moisture. Then the cloth is again dipped into the dye bath and the mixture again rubbed in for about 5 minutes, after which it is wiped clean and hung up to dry. Another simple method of dyeing with turmeric, used in Ethiopia, is to put the cloth to be dyed into a boiling decoction of the turmeric paste. In Asia turmeric is mostly used for cotton and silk cloth to obtain various shades of golden to orange-yellow. In Europe it was used in wool dyeing, to obtain special shades of golden-yellow in combination with weld (*Reseda luteola* L.) and bright scarlet, where turmeric was applied as a ground-dye for cochineal (*Dactylopius coccus*).

Genetic resources A germplasm collection of 500–600 *Curcuma longa* accessions is maintained at the NBPGR Regional Station, Thrissur, Kerala, India.

Breeding The average productivity and quality of turmeric are far from satisfactory. Until recently, there has been hardly any work on crop improvement in *Curcuma longa*, because conventional methods of breeding are hampered by problems of sterility. Clonal selection is now being applied to exploit the naturally occurring variation, and mutation breeding is being practised. The major breeding objectives are creating cultivars with high yield and appropriate curcumin content and colour tone, without excessive volatile oil content and with resistance against rhizome rot.

Prospects *Curcuma longa* is an important food colorant, spice and medicinal plant. The growing demand for turmeric as a spice and as a safe food colouring agent in local as well as international markets indicates that its prospects are good. Crop improvement, agronomic research and pest management need to be undertaken to obtain high production levels and good quality. Turmeric is an interesting crop for incorporation in a mixed cropping system with shrubs and young trees. Studies on the bioactive compounds of the rhizomes have opened up new possibilities for the use of turmeric in pharmaceutical products. Given the dominant position of India in both production and trade, it will be difficult for the crop to expand in Africa for the international market. Expansion for local use may offer better opportunities.

Major references Ammon & Wahl, 1991; Burkill, 1966; Burkill, 2000; Burtt, 1977; Dahal & Idris, 1999; Dalziel, 1926; Green, 1995; Purseglove, 1972; Purseglove et al., 1981; Trimurti H. Wardini & Budi Prakoso, 1999.

Other references Abdul Kader, Vedamuthu & Balashanmugam, 1994; Adjanohoun et al., 1983a; Annamalai, 1994; Cardon, 2003; Debray, Jacquemin & Razafindrambao, 1971; Decary, 1946; George, 1994a; George, 1994b; Gurib-Fakim, Guého & Bissoondoyal, 1997; Husain, 1992; Jansen, 1981; Kibungo Kembelo, 2004; Latham, 2004; Lavergne & Véra, 1989; Nadgauda et al., 1978; Nair et al. (Editors), 1982;

Novy, 1997; Rakotonomenjanaharty, 1996; Rama Rao & Rao, 1994; Rethinam, Sivaraman & Sushama, 1994; Tournerie, 1986; USDA, 2004a; Westphal, 1975.

Sources of illustration Dahal & Idris, 1999.

Authors P.C.M. Jansen

Based on PROSEA 13: Spices.

DANAIS LIGUSTRIFOLIA Baker

Protologue Journ. Linn. Soc., Bot. 20: 162 (1883).

Family Rubiaceae

Origin and geographic distribution *Danais ligustrifolia* is endemic to Madagascar.

Uses The roots of *Danais ligustrifolia* are one of the main sources of orange to red dyes, used in traditional textiles in Madagascar to dye raffia and silk. Red is one of the most important colours in these textiles, for instance in 'raffia ikats'. Raffia ikats are long pieces of raffia cloth in which some portions of the warp yarns are tied with thick threads to protect the patterns before dyeing the yarn; successive patterns of tying and dyeing in different dye baths create multicoloured designs, usually in the natural ivory colour of the raffia fibre, red, orange or pink, two shades of blue, black and yellow or green. Red vegetable dye is also very important in the 'lamba mena', fine textiles used as shrouds. Before dyeing it with the root of *Danais ligustrifolia*, the fibre is prepared by boiling it in water to which ash is added, then it is washed and dried. The roots of *Danais ligustrifolia* are pounded and put into almost boiling water; usually 2 parts of root with 3 parts of water make up the total volume of the dye bath. Then the fibre is added, submerged and left for 1–6 hours, depending on the intensity of the colour wanted. Subsequently the dyed fibre is washed again and dried. Many *Danais* species also have medicinal uses in Madagascar and neighbouring islands, the roots being used against herpes and the bark as a febrifuge.

Properties Like other *Danais* species, the bark and roots of *Danais ligustrifolia*, most probably contain the anthraquinones danain and danaidin, which are the sources of the orange and red dyes obtained from these plants. The leaves of many *Danais* species contain high proportions of aluminium (up to 1% of the dry matter weight in *Danais fragrans* (Comm. ex Lam.) Pers.), which can be used as an organic mordant since aluminium salts are the most useful substances employed in dyeing processes, to strengthen and multiply the chemical bonds between textile fibres and most natural dyes.

Botany Liana or climbing shrub, with stems up to 25 m long. Leaves decussately opposite, simple, entire, glabrous; stipules deltoid, c. 2 mm long; petiole 3–10 mm long; blade elliptical to lanceolate-ovate, 3–12 cm × 1.5–4.5 cm, base cuneate, apex acuminate. Inflorescence a usually terminal, pyramidal panicle with cymose branches, up to 14 cm × 10 cm; peduncle up to 3.5 cm long. Flowers bisexual, regular, 5-merous, heterodistylous, fragrant; pedicel up to 1 mm long; calyx tubular with triangular lobes up to 2.5 mm long; corolla tubular, tube funnel-shaped, up to 4.5 mm long, greenish white, hairy in throat, lobes oblong, up to 2 mm long, yellow-orange; stamens included in long-styled flowers, exserted for c. 4 mm in short-styled flowers; ovary inferior, globose, c. 1 mm in diameter, style plus stigma 6–8 mm long in long-styled flowers, shorter than corolla tube in short-styled flowers, stigma lobes 2. Fruit a globose capsule c. 3 mm in diameter, thin-walled, glabrous. Seeds c. 1 mm in diameter, dark brown, with a broad, irregularly lacerate wing.

Danais comprises about 25 species, most of them endemic to Madagascar. The genus is closely related to the Madagascan genera *Schismatoclada* (about 20 species) and *Payera* (about 10 species), the 3 forming a complex partly fitting in subfamily *Rubioideae*, and partly in subfamily *Cinchonoideae*, which makes its systematic position in *Rubiaceae* still unclear. *Danais ligustrifolia* closely resembles *Danais microcarpa* Baker, also endemic to Madagascar, whose leaves are usually smaller. The roots of several other *Danais* species are similarly used as sources of red dyes, the most important species being *Danais cernua* Baker, *Danais rhamnifolia* Baker (synonym: *Danais chapelieri* Drake) and *Danais volubilis* Baker (synonym: *Danais latisepala* Homolle). A paste of pounded rootbark of *Danais rhamnifolia* dyes raffia a dark blood red. With some lemon juice added, the roots of *Danais cernua* dye a deep red, while those of *Danais volubilis* dye more orange. *Danais cernua* is widespread all over Madagascar; its leaves are mostly opposite, but occasionally arranged in whorls of 3 and measure up to 9 cm × 4 cm. When its tissue is damaged an unpleasant foetid odour is emitted, possibly caused by the iridoid glycoside paederoside. *Danais volubilis*, endemic to

Madagascar, has its leaves always in whorls of 3 (or sometimes 4) and has larger flowers and fruits. *Danais rhamnifolia* is endemic in eastern Madagascar and is closely related to *Danais microcarpa* and *Danais ligustrifolia*. It has larger, membranous leaves, larger inflorescences with flowers that have typically thin, filiform corolla tubes. Flowering of *Danais ligustrifolia* is mainly in March–June, fruiting in October–June.

Ecology *Danais ligustrifolia* occurs in the eastern lowland rainforest of Madagascar, sometimes in valleys and ravines, from sea-level up to 1000 m altitude.

Genetic resources and breeding *Danais ligustrifolia* is rather widespread in Madagascar and does not seem to be in danger of genetic erosion as long as its habitat is not endangered.

Prospects *Danais ligustrifolia* and other *Danais* species represent interesting sources of orange to red dyes, with the aluminium present in the leaves functioning as a mordant. In Madagascar, several development programmes are presently promoting the renewed use of natural dyes, including the reds from various *Danais* species, in the production of raffia, silk and mohair textiles, inspired by traditional textiles and created by young Malagasy fashion designers. Possibilities for cultivation and chemical compositions deserve further investigation.

Major references Boiteau, Boiteau & Allorge-Boiteau, 1999; Decary, 1946; Puff & Buchner, 1994.

Other references Buchner & Puff, 1993; Jansen et al., 2000; Jansen et al., 2003.

Authors P.C.M. Jansen

DIOSPYROS LOUREIRIANA G.Don

Protologue Gen. hist. 4: 39 (1837).

Family Ebenaceae

Synonyms *Diospyros macrocalyx* Klotzsch (1861), *Royena macrocalyx* (Klotzsch) Gürke (1895), *Diospyros usambarensis* F.White (1963).

Vernacular names Dye diospyros (En). Nhamodema (Po). Mdaa, mdala mweupe (Sw).

Origin and geographic distribution *Diospyros loureiriana* is common and widespread in Kenya, Tanzania, Malawi, Zimbabwe and Mozambique.

Uses In Kenya a black dye for mats and wickerwork is extracted from the roots of *Diospyros loureiriana* by pounding and boiling. The fibres to be dyed are steeped into the solution and then mordanted in black ferruginous mud, iron sulphate or iron rust dissolved in organic acid. A black dye for raffia and cotton cloth can also be extracted from the pounded bark and applied in the same way. In Mozambique a dark red dye used to redden lips and teeth is obtained by crushing the roots into a pulp. The fruits are edible. The wood is hard and white and can be used for small utensils and as firewood. Chewed fresh roots and a root extract are applied externally to snakebites, or the extract is drunk.

Properties The dyeing properties of the bark and roots are due to a combination of naphthoquinones and naphthoquinone dimers and trimers, among which 7-methyljuglone, a derivate of juglone, the dye present in walnut trees (*Juglans* spp.). The proportions of these colorants have been found to vary according to the seasons. The main components isolated from the root bark of *Diospyros loureiriana* collected in the rainy season in Tanzania (January) are the naphthoquinones diosindigo A, 7-methyljuglone, mamegakinone, diosindigo B and bis-isodiospyrin. The main component of dried powdered root bark collected during the dry season (September) was 7-methyljuglone. The stem bark contains diosindigo A and 7-methyljuglone. Dried powdered root bark has fungicidal and molluscicidal properties. In bioassays it was found that 5 ppm 7-methyljuglone was lethal to *Biomphalaria glabrata* snails within 24 hours, and 0.025 μg was sufficient to prevent growth of the fungus *Cladosporium cucumerinum*. Triterpenoids (including α-amyrin, betulinic acid and various mixtures) were isolated from the leaves.

Botany Dioecious, semi-deciduous shrub or small tree up to 6(–10) m tall; bark corky, rough, deeply fissured, grey or black; twigs with reddish hairs. Leaves alternate, simple and entire; stipules absent; petiole up to 1.5 cm long; blade oblong to obovate-oblong, 1–12 cm × 1–7 cm, base rounded to slightly cordate, apex rounded to acute, almost glabrous to densely pubescent below, lateral veins in 5–6 pairs. Inflorescence an axillary cyme, few-flowered. Flowers unisexual, regular, 4-merous; pedicel up to 1.5 cm long; calyx 3–4 mm long, deeply lobed, lobes triangular, reflexed, accrescent in fruit; corolla 4-lobed almost to the base, 4–6 mm long, white, yellow-white or green-white; disk undulate; male flowers with 8 stamens and rudimentary ovary; female flowers with superior, 8-celled ovary crowned by 4 styles united at base, and 8 staminodes. Fruit a globose berry up to 3 cm in diameter, yellow, shortly hairy, up to 8-seeded, enclosed by the calyx lobes. Seeds up to 14 mm × 7 mm, dull brown, smooth.

Diospyros is a large, pantropical genus of about 500 species; in tropical Africa about 90 species occur and several species produce valuable timber or edible fruits. Many species are used as a dye source in Africa, e.g. the roots of *Diospyros lycioides* Desf. yield a popular yellow-brown dye in southern Africa, but the species is most important for its fibrous roots and twigs used as toothbrush sticks. A leaf decoction of *Diospyros sonbreana* F.White gives a black ink that is used in Côte d'Ivoire, but the species is more important medicinally. Two subspecies have been distinguished in *Diospyros loureiriana*, mainly based on differences in hairiness, but intermediates exist.

Ecology *Diospyros loureiriana* is very common on poor soils in sunny locations in wooded or grassy savanna, often in *Brachystegia-Julbernardia* woodland, from sea-level up to 750 m altitude.

Genetic resources and breeding *Diospyros loureiriana* is widespread and not in danger of genetic erosion.

Prospects *Diospyros loureiriana* is a good source of fast reddish brown to black dyes that will remain locally useful in the basket-weaving craft. The medicinal properties need further investigation.

Major references Burtt, 1935; Greenway, 1941; van Wyk & Gericke, 2000; White & Verdcourt, 1996.

Other references Coates Palgrave, 1983; Khan, Kishimba & Locksley, 1989; Khan, Nkunya & Wevers, 1980; Kokwaro, 1993; Marston, Msonthi & Hostettmann, 1984; Miège, 1992; van der Vijver & Gerritsma, 1973; van der Vijver & Gerritsma, 1974; Watt & Breyer-Brandwijk, 1962; White, 1983a.

Authors P.C.M. Jansen

ELEPHANTORRHIZA ELEPHANTINA (Burch.) Skeels

Protologue U.S. Dept. Agric. Bur. Pl. Ind. Bull. 176: 29 (1910).

Family Mimosaceae (Leguminosae - Mimosoideae)

Synonyms *Acacia elephantina* Burch. (1824), *Elephantorrhiza burchellii* Benth. (1841).

Vernacular names Elephant root, elandsbean (En).

Origin and geographic distribution *Elephantorrhiza elephantina* is found in southern Africa in Namibia, Botswana, Zimbabwe, Mozambique, Swaziland, Lesotho and South Africa.

Uses The bark of the tuberous rhizome (usually including the roots) of *Elephantorrhiza elephantina* is a popular source of tanning and dyeing materials, collected from the wild and sold on local markets in southern Africa. Rhizomes or their bark only are crushed, some water is added and the resulting paste is applied to hides to tan and dye them a reddish colour described as a pale wine colour in Botswana. This treatment also serves to soften the leather. To dye grass for mat and basket weaving, the pounded rhizomes are boiled with the grass for several hours, giving a khaki, brown or reddish brown colour. The young shoots are eaten by livestock. The seed has a sweetish taste followed by a burning sensation, but roasted it has been used as a coffee substitute. Medicinally, the rhizome is used as a general remedy for intestinal and abdominal complaints (diarrhoea, dysentery, stomachache, painful menstruation) for humans and animals, as a relief for heart troubles and haemorrhoids, and to cure skin diseases and acne. The root is steeped in water for 24 hours or longer, after which it is strained and ready for external use. For internal use, the infusion has to be boiled for 10 minutes first. The face is held in the vapour arising from a warm infusion to treat acne. In Zimbabwe an infusion is taken by women against infertility and as an aphrodisiac.

Properties The rhizome of *Elephantorrhiza elephantina* contains 6–22% tannin and 17% sugar. The bark contains 25–30% tannin. The rhizome extract contains too much sugar for commercial exploitation as it tends to ferment. The leather gets dyed in reddish tones that may be undesirable when light-coloured leather is needed. Dye experiments on wool with a rhizome extract gave different colours according to the mordants used, e.g. yellow with stannous chloride, golden to orange with chromium chloride, orange-brown with ammonium molybdate, black with ammonium vanadate, and salmon with sodium wolfram or zinc sulfate. The seed yields 10% of a fixed oil. The seed is toxic to sheep (lethal dose 250 g), rabbits (lethal dose 5–7.5 g/kg) and guinea-pigs, causing gastro-enteritis and pulmonary oedema.

Botany Low shrub, producing at ground level annual stems 20–90 cm tall from the woody end of an elongate, often thickened rhizome up to 8 m long. Leaves alternate, bipinnately compound, almost glabrous; petiole up to 8 cm long, rachis up to 18 cm; pinnae 2–4 pairs in lower leaves, 7–17 in upper ones, axis up to 10 cm long; leaflets up to 55 pairs per pinna, linear to oblong, 4–15 mm × 0.5–2.5 mm, base asymmetric, apex acute and usually mucronate. Inflorescence an axillary raceme, usually confined to the lower part of the stem, solitary or clustered, including peduncle up to 12 cm long. Flowers bisexual, regular, 5-merous; pedicel up to 1.5 mm long, at base with red-brown glands, articulated near the middle; calyx campanulate, almost 2 mm long, toothed; petals free or slightly connate basally, linear-oblong, 2–4 mm × 1 mm, yellow-white; stamens 10, free, filaments up to 6.5 mm long; ovary superior, shortly stipitate, style filiform, stigma terminal. Fruit a compressed-oblong, straight or slightly curved pod 5–21 cm × 3–6 cm, red-brown, prominently transversely veined, often swollen over the seeds, the valves separating from the persistent margins, the outer layer of the fruit wall peeling off the inner layer and the layers breaking up irregularly. Seeds compressed-ellipsoid, 18–26 mm × 13–18 mm × 6–13 mm.

Elephantorrhiza comprises 9 species, all restricted to Africa south of the equator. *Elephantorrhiza elephantina* is quite variable in the number of pinnae and number, size and shape of leaflets. In the eastern part of its distribution area plants tend to have most pinnae with smallest leaflets. The outer layer of the ripe fruit is rather hard but readily absorbs water and starts to disintegrate soon. Seeds often germinate within the moist disintegrating fruits on the surface of the soil.

In Botswana the rhizome of the related but larger *Elephantorrhiza burkei* Benth. is also used for tanning and dyeing, giving a khaki colour, while the bark is used as an astringent. The crushed rhizomes of *Elephantorrhiza suffruticosa* Schinz, found from Namibia to Mozambique, were used as red dye for the tanned cow stomachs formerly worn as aprons or skirts by the Kwanyama Ovambo women of northern Namibia. In Zimbabwe the rhizome is applied against constipation and diarrhoea. From the roots and stem of *Elephantorrhiza goetzei* (Harms) Harms, a small tree found from Angola to Tanzania and further southwards, compounds (e.g. flavans, stilbene glycosides) with promising antimicrobial and anthelmintic activities have been isolated. In Malawi its fibrous stem bark is used as rope and the tannin-rich roots as a fish poison.

Ecology *Elephantorrhiza elephantina* often occurs gregariously in hot, dry areas with grassland and open scrub.

Genetic resources and breeding Although *Elephantorrhiza elephantina* is widespread, overharvesting of rhizomes for tanning or medicinal purposes might endanger populations so that germplasm collection is recommended.

Prospects *Elephantorrhiza elephantina* is only of minor importance locally in rural areas in southern Africa as a tannin, dye and medicine source. More research is required for reliable expectations.

Major references Rodin, 1985; Ross, 1974; van Wyk & Gericke, 2000; Watt & Breyer-Brandwijk, 1962.

Other references Brenan, 1970; Gelfand et al., 1985; Mølgaard et al., 2001; Moyoa, Gasheb & Majinda, 1999; Neuwinger, 2000; Phillips, 1923; Ross, 1975; van Wyk, van Oudtshoorn & Gericke, 1997; Wanjala & Majinda, 2001; Williamson, 1955.

Authors P.C.M. Jansen

EUCLEA DIVINORUM Hiern

Protologue Trans. Camb. Phil. Soc. 12: 99 (1873).

Family Ebenaceae

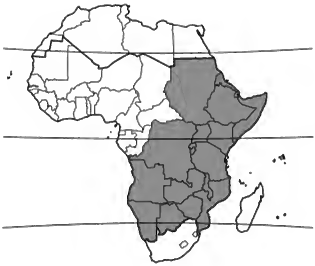
Chromosome number $2n = 30$

Synonyms *Euclea keniensis* R.E.Fr. (1925).

Vernacular names Magic gwarri, diamond-leaved euclea (En). Mdaa, mdala, msirisha (Sw).

Origin and geographic distribution *Euclea divinorum* is widespread from Sudan and Ethiopia to Namibia, Botswana and South Africa.

Uses The bark of *Euclea divinorum* is collected from the wild and used to produce fast reddish-brown dyes, and for tanning hides and skins. Dyeing is important e.g. in Botswana, where strips made of the young leaves of the palm *Hyphaene petersiana* Mart. used in basket weaving are coloured various shades of brown. Depending on how long the fibre to be dyed is left in the boiling dye extract, the colour obtained can range from pale to dark brown or black. In Tanzania and southern Africa, the roots are pounded and boiled to dye the various vegetable fibres used in the weav-



Euclea divinorum – *wild*

ing of mats into various shades of brown and even black when a mordant of iron-rich mud is applied after dyeing. When used to dye wool, the roots give a wide range of brown colours. Leather produced by tanning with *Euclea divinorum* bark has a deep red colour due to the numerous naphthoquinones present in the plant. The bark provides an attractive alternative to black wattle (*Acacia mearnsii* De Wild.) and other available tanning barks.

In East Africa an infusion of the bark is used as a condiment in the preparation of a fatty meat and milk soup. The thin fleshy part of the fruits is edible, but not very palatable; fruits are taken as a mild laxative, but can have strong purgative action. The fruits are used as a purple dye for basket fibres by the Kwanyama Ovambos of northern Namibia and also boiled to produce purple ink. They are applied in the fermentation process to make beer. The roots and twigs are popular as toothbrushes and roots are chewed as a disinfectant and to colour the lips and mouth red. In East Africa the wood is used for tool handles and carving, and as firewood. In traditional medicine root extracts and dried powdered roots are applied for the treatment of gastro-intestinal disturbances, cancer, ulcers, wounds, arthritis, miscarriage, jaundice, snakebites and gonorrhoea. The Shangaan people apply ground roots on the skin against leprosy and to relieve headache and toothache. In western Kenya *Euclea divinorum* is one of the species used in the treatment of milk to increase its digestibility, palatability and preservation; sometimes treated milk can be stored for over a year without turning bad, which is vital to the household food security. In south-western Ethiopia *Euclea divinorum* is used to purify drinking water by adding branches to the gourds or pots and leaving them to soak in the water for several hours. Occasionally, *Euclea divinorum* serves as an ornamental and shade tree.

Production and international trade Bark, roots, twigs, fruits and wood of *Euclea divinorum* are collected from the wild and traded only locally; they do not enter international trade. Twigs and roots for use as toothbrushes are often sold on local markets.

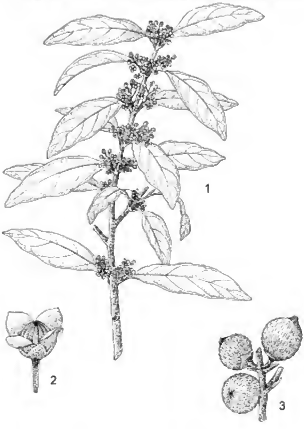
Properties The bark of *Euclea divinorum* has a high tannin content. Analyses of bark collected in Tanzania revealed a total phenolic content of 122–148 mg/g, a water soluble phenolic content of 77–87 mg/g and a tannin content (measured by protein precipitation) of 94–95 mg/g. The tannin/non-tannin ratio among extractable phenolics is 2.4 and compares well with the most promising eastern African acacias in terms of tanning potential. Dried bark, boiled for 1.5 hours in water, yielded a tannin liquor with a strength of 7 Bé (specific gravity (s.g.) 1.0501, using a Baumé hydrometer). The best result for other locally available barks was obtained from *Acacia nilotica* (L.) Delile: it reached only 3 Bé (s.g. 1.0209). For tanning 2 Bé (s.g. 1.0138) is sufficient, but the advantage of the higher strength reached with bark of *Euclea divinorum* is that less bark is necessary to tan a given quantity of hides or skins to leather.

The root-bark of *Euclea divinorum* contains a rich combination of dyeing compounds making this species an interesting fast dye that can be used with or without the addition of metallic salts as mordants, due to the mordanting effect of the tannins present in the plant. Research on the root-bark done in Zimbabwe resulted in the isolation of naphthoquinones and napthoquinone dimers and trimers: 7-methyljuglone (juglone being the main colorant in walnuts, *Juglans* species), isodiospyrin, and flavonoids which contribute together to the dyeing properties of the plant. Triterpenoids were also isolated. One of the triterpenoid compounds and 7-methyljuglone showed cytotoxicity, the latter against a wider range of cell lines than the former. Chemical investigation of the aerial parts of *Euclea divinorum* done in Ethiopia resulted in the isolation of 4 flavonoid compounds: (+)-catechin, glycosides of aromadendrin, quercetin and myricetin.

Some evidence exists that twigs of *Euclea divinorum* used as a toothbrush not only clean the teeth but also inhibit growth of teeth-attacking bacteria because of their high polyphenolic content.

The wood is white with brown spots and is heavy, hard and strong. The sapwood is pinkish to cream-coloured, turning apricot colour on exposure to air.

Description Evergreen, dioecious shrub or small tree up to 6(–15) m tall, glabrous except for peltate scales on twigs, leaves and inflorescence axes; bark grey-brown, red-brown, pale mauve-grey or cinnamon to black, mostly rough with shallow irregular longitudinal fissures, flaking longitudinally. Leaves opposite, simple; petiole 4–6 mm long; stipules absent; blade elliptical to rhombic or narrowly rhombic-lanceolate, up to 12 cm × 4.5 cm, base rounded to cuneate, apex rounded to emarginate, margin often undulate, leathery, pinnately veined but veins usually inconspicuous. Inflorescence an axillary, dense and contracted false raceme up to 1.5 cm long, sometimes paired. Flowers unisexual, regular, 4–5-merous; calyx shallowly cup-shaped with obtuse-triangular teeth; corolla deeply cup-shaped, with white to pale yellow or salmon buff lobes, bristly hairy along the midribs; male flowers c. 3.5 mm long, with 10–17 stamens in 2 rows; female flowers smaller, without staminodes, ovary yellow, bristly hairy, 4-celled, styles 2. Fruit a somewhat fleshy globose berry 5–7 mm in diameter, brown-black to purple with short white hairs, usually 1-seeded. Seed globose, 4–5 mm in diameter, with 3 radiating lines from the apex, brown.



Euclea divinorum – 1, flowering branch; 2, male flower; 3, fruits.
Redrawn and adapted by Iskak Syamsudin

Other botanical information *Euclea* comprises about 12 species and is confined to Africa and Arabia. South Africa is richest in species. *Euclea divinorum* is less variable than other *Euclea* species. Specimens intermediate between *Euclea divinorum* and *Euclea crispa* (Thunb.) Gürke (synonym: *Euclea lanceolata* E.Mey ex DC.) are common in southern Africa and are probably hybrids. *Euclea crispa* is used for dyeing mats and for tanning in Malawi (its root bark contains 7-methyljuglone and 4 naphthoquinone dimers), but it is more important as a medicinal plant. *Euclea natalensis* A.DC. (distributed from Kenya and DR Congo southwards to South Africa) has dye and tannin uses similar to those of *Euclea divinorum*, but is primarily used in traditional medicine. The quinones so far isolated from *Euclea natalensis* include 7-methyljuglone and methylnaphthazarin, the naphthoquinone dimers diospyrin, isodiospyrin, biramentaceone, mamegakinone, natalenone, 8'-hydroxydiospyrin and euclanone and 2 trimers, galpinone and another compound of still incompletely elucidated structure.

In the basket weaving industry in Botswana, in addition to *Euclea divinorum*, the bark of *Berchemia discolor* (Klotzsch) Hemsl., leaves of *Indigofera* species and fungus-infested *Sorghum* husks are also used for dyeing the fibre materials, respectively giving shades of brown, mauve and pink.

Ecology *Euclea divinorum* occurs in grassland with scattered trees and open bushland, often on termite mounds, but also in secondary forest, margins of evergreen forest and on stony slopes, from sea-level up to 2700 m altitude. It is moderately tolerant of heavy metals, tolerating high concentrations of nickel, but only relatively low levels of copper, and often becomes locally abundant on metalliferous soils. It is particularly common on arsenical soils, which are often associated with gold deposits or reefs, and it has been suggested that it may have value as an indicator of the presence of gold. The successional dynamics of *Acacia-Euclea* savannas appear to depend on the browsing by large mammals. *Euclea* thickets tend to dominate in savanna areas without elephants.

Propagation and planting Although *Euclea divinorum* is rarely cultivated, it can be propagated by suckers, transplanting seedlings or direct seeding. There are about 30,000 seeds/kg. The seeds are perishable and lose viability within about 2 months. They germinate readily; no pretreatment is necessary. *Euclea divinorum* has a good coppicing ability and root suckers are common, growing up some distance from the tree.

Management *Euclea divinorum* tends to dominate pastures to the detriment of wildlife and pastoralism. In some situations only the use of arboricides can solve the problem.

Handling after harvest The tanning liquor is made by boiling the bark of *Euclea divinorum* in water until the required concentration is obtained (from 2 Bé = s. g. 1.0138 upward). Hides and skins to be tanned are treated with the extract at ambient temperatures. For dyeing, the roots are dug up and beaten to bruise the bark. Approximately equal quantities of fresh roots and palm leaves or other fibres are required. The fibres and textiles to be dyed are simply left for some time in the boiling extract and subsequently dried. Among the Kwanyama Ovambos of northern Namibia, fruits mixed with those of *Berchemia discolor*, are crushed and boiled with palm leaf strips and the mixture is allowed to stand for one to several days to produce a purplish-brown dye to decorate baskets. Used alone and without mordant, they give a purple colour that is less fast than the darker colour obtained with the mixture.

Genetic resources *Euclea divinorum* is widespread in Africa and is not in danger of genetic erosion. Locally, over-exploitation for bark or wood may cause temporary disappearance. However, due to its great power of coppicing and root suckering, *Euclea divinorum* is less susceptible to over-exploitation than acacia and its exploitation could improve pastoral land.

Prospects With its good tanning and medicinal properties, its interesting dye composition and great regeneration power *Euclea divinorum* is a very useful and promising plant, even growing well on soils polluted with heavy metals. Its bark is considered a high potential tanning material, offering a cheap alternative for black wattle bark in rural pastoral communities. In areas where overexploitation has led to its local disappearance (e.g. in basket weaving centres in Botswana), cultivation is recommended.

Major references Cunningham & Milton, 1987; Mann, 1960; Rodin, 1985; van Grinsven, Parkipuny & Johns, 1999; van Wyk & Gericke, 2000; White, 1983a; White & Verdcourt, 1996.

Other references Beentje, 1994; Coates Palgrave, 1983; Dagne, Melaku & Sterner, 1993; de Winter, 1963; den Biggelaar & Mueithi, 2000; Ferreira et al., 1977; Gelfand et al., 1985; Homer, Manji & Beighton, 1990; Johns et al., 1995; Kokwaro, 1993; Mbuya et al., 1994; Mebe, Cordell & Pezzuto, 1998; Palmer & Pitman, 1972–1974; Smith & Goodman, 1987; Wild, 1974; Tabuti, Lye & Dhillion, 2003; Williamson, 1955.

Sources of illustration White & Verdcourt, 1996.

Authors P.M. Njuguna

FICUS GLUMOSA Delile

Protologue Cent. pl. Voy. Méroé: 63 (1826).

Family Moraceae

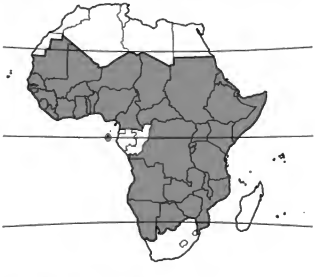
Chromosome number $2n = 52$

Synonyms *Ficus sonderi* Miq. (1867).

Vernacular names African rock fig, mountain fig (En). Mkuyu (Sw).

Origin and geographic distribution *Ficus glumosa* is widespread throughout most of tropical Africa, extending to western Saudi Arabia in the east and South Africa in the south.

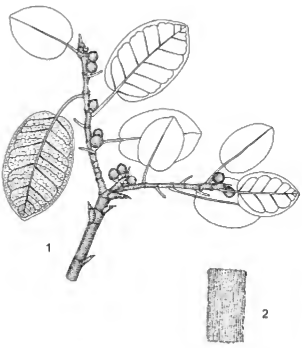
Uses The bark, rich in tannin, is used in central, eastern and southern Africa for tanning hides. In Kaokoland in Namibia it is said to be the most important tanning agent for leather, giving it a red colour favoured by the



Ficus glumosa – wild

Himba people. The bark is also a source of a brick-red dye, popular in Mali ('bogolan' dyeing process), Sierra Leone (Koranko people) and Ghana for dyeing cloth and raffia. In some areas, e.g. Sudan, cloth is made from the bark. The bark also contains abundant sticky white latex which is used in Ghana like bird-lime to trap crickets. In Uganda it is chewed as chewing-gum and in West Africa the Tenda people use the latex for fastening arrowheads to their shaft. Young leaves are eaten as a vegetable (e.g. in soup in Ghana) and are browsed by cattle. The fruit is edible when fully ripe and said to be the most flavoursome of the wild figs in Senegal. The wood is light and used for firewood and charcoal. Sometimes trees are planted as a live fence or as windbreak. Medicinal uses are numerous. In Côte d'Ivoire latex is applied to alleviate pain from sprains and latex diluted in water is used in the Central African Republic to treat diarrhoea. In Zimbabwe latex is dropped into the eyes against sore eyes. Powdered bark, mixed with latex, is used in Nigeria to plug carious teeth and in the Central African Republic a decoction of the bark is used as a mouthwash against toothache. A bark macerate is applied on the eyes of new born babies in Senegal (Casamanca) to prevent conjunctivitis. Tenda people apply pounded bark topically against headache. In East Africa pounded bark, soaked in water, is drunk against stomach disorders. In Tanzania a decoction of pounded bark is used to wash sores daily until recovery. In Senegal and Côte d'Ivoire the roots and fruits are used in preparations to cure female sterility.

Description Shrub or small tree up to 10 m tall; outer bark flaking, inner bark exuding sticky white latex; leafy twigs glabrous or white hairy. Leaves arranged spirally, simple and entire; stipules up to 1.5 cm long, falling off early; petiole up to 8 cm long; blade oblong, broadly elliptical, broadly ovate, obovate or almost circular, 2–19 cm × 1–13 cm, base cordate or rounded, apex acuminate to subobtuse, glabrous to densely hairy above, densely hairy below, lateral veins in 3–7 pairs, tertiary venation reticulate. Inflorescence a fig, consisting of an urn-shaped receptacle with a narrow apical opening, the flowers enclosed within, figs solitary or in pairs in the leaf axils or just below, almost sessile, globose to ellipsoid, 1–1.5 cm in diameter, glabrous to densely tomentose, orange to red, at the fruiting stage often with darker spots. Flowers unisexual, with 2–4 tepals; male flowers with one stamen; female flowers with 1-celled ovary and short or long style. Fruit a drupe, 1-seeded, developing within the fig.



Ficus glumosa – 1, flowering branch; 2, part of branch with bark.
Redrawn and adapted by Achmad Satiri Nurhaman

Other botanical information *Ficus* comprises about 750 species, occurring in tropical and subtropical regions, with a few species in warm temperate regions. About 100 species occur in Africa, 500 in Asia and Australia, and 150 in America. *Ficus glumosa* belongs to subgenus *Urostigma*, section *Galoglychia*. Particularly the indumentum on its leaves varies strongly, usually being most dense in the southern part of its range and almost absent in north-eastern Africa. *Ficus glumosa* can easily be confused with *Ficus stuhlmannii* Warb., which is characterized by the more prominent tertiary venation of the lower leaf surface. The bark and leaves of several other species are used for tanning or as sources of red, brown or green dyes.

Ficus ilicina (Sond.) Miq. (synonym: *Ficus guerichiana* Engl.) is a shrub or small tree up to 5 m tall, sometimes lianescent, with smooth but flaky bark, roots often plastered over rocks, elliptical, oblong or oblanceolate leaves 3–9 cm × 3–5 cm and globose figs, c. 1 cm in diameter, solitary or in pairs. It occurs on rocky places in dry areas in south-western Angola, Namibia and South Africa. Its bark is used for the tanning and dyeing of hides and the fruits are eaten.

The bark of *Ficus cordata* Thunb. is used in southern Africa for the tanning and dyeing of hides but this species is more important as an ornamental. The bark of *Ficus lutea* Vahl is used in Madagascar to obtain red-ochre dyes for raffia and silk textiles, but its major use is also ornamental. In Mali the barks of *Ficus platyphylla* Delile and *Ficus sycomorus* L. are dye sources for bogolan textiles giving red-ochre to brownish colours, but the former is more important for its latex, used in chewing gum and the latter for its fruits, cooked as a vegetable in soups or in couscous.

Growth and development The pollination in the figs is effected by *Elisabethiella glumosae* wasps. These enter the fig via the osteole, a bract-covered apical pore. Once inside, they pollinate the female flowers and deposit their eggs in the ovaries. However, only the short-styled ovaries can be reached by the wasps, and these serve to hatch the larvae, while the seeds develop in the long-styled ovaries. Birds eat the fruits and probably disperse the seeds.

Ecology *Ficus glumosa* occurs on rock outcrops and rocky slopes in dry areas, less often in riverine and open *Brachystegia* woodland, occasionally on termite mounds. It is found up to 2000 m altitude.

Propagation and planting *Ficus glumosa* can be propagated by seed and cuttings.

Handling after harvest To make a tanning liquor, the bark is finely chopped and soaked in water. The hides are then steeped in the liquid. In Mali bogolan techniques of dyeing often combine dyes from several species to increase the solidity of the colours. The barks of *Ficus glumosa*, *Ficus platyphylla* or *Ficus sycomorus* are finely chopped and boiled in water. The cloth is soaked in this dye and then dried in the sun. Then comes the 'fixing dye', a bath in a decoction of the leaves of *Anogeissus leiocarpa* (DC.) Guill. & Perr. The cloth is again left to dry in the sun. The 'fixing bath' and sun drying process are repeated three times at least, and then the cloth is soaked again in the first dye bath with *Ficus* bark and finally dried in the sun.

Genetic resources *Ficus glumosa* is very widespread and although it is nowhere very common, it is not in danger of genetic erosion.

Prospects *Ficus glumosa* is a multipurpose tree or shrub, particularly valuable in drier areas for its edible young leaves and ripe fruits. More research is needed for a better understanding of the dye and tannin properties of the bark and the numerous reported medicinal properties.

Major references Arbonnier, 2004; Berg, 1991; Berg & Wiebes, 1992; Burkill, 1997; Decary, 1946; International Centre for Research in Agroforestry (ICRAF), undated c; Irvine, 1961; Marquet, in press; Miège, 1992; van Wyk & Gericke, 2000.

Other references Adjanohoun et al., 1989; Adjanohoun & Aké Assi, 1979; Aweke, 1979; Berg, 1990; Berg & Hijman, 1989; Berg, Hijman & Weerdenburg, 1985; Coates Palgrave, 1983; Gelfand et al., 1985; Hauman, Lebrun & Boutique, 1948; Katende, Birnie & Tengnäs, 1995; Kokwaro, 1993; Palmer & Pitman, 1972–1974; Sommerlatte & Sommerlatte, 1990; van Greuning, 1990.

Sources of illustration Aweke, 1979.

Authors P.C.M. Jansen

FLEMINGIA GRAHAMIANA Wight & Arn.

Protologue Prodr. fl. Ind. orient. 1: 242 (1834).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Synonyms *Flemingia rhodocarpa* Baker (1871), *Moghania grahamiana* (Wight & Arn.) Kuntze (1891), *Moghania rhodocarpa* (Baker) Hauman (1954).

Origin and geographic distribution *Flemingia grahamiana* is widespread in tropical Africa, from Ghana east to Ethiopia and south to South Africa, extending via Arabia to southern India. In Yemen it has been cultivated as a dye and medicinal plant since ancient times. Formerly it was also cultivated in Ethiopia and the dye was exported to Yemen.

Uses *Flemingia grahamiana* is one of the principal sources of the Arab dye called 'waras', 'wars' or 'warus'. Waras is a coarse purple or brilliant orange-brown powder, consisting of single (not grouped) hairs and dark gland globules rubbed from dry fruits. The powder is used in India, the Arab world and in Africa (e.g. in Uganda, Zimbabwe and Malawi), mainly for dyeing silk and cotton a golden-yellow, but also for other purposes such as dyeing bamboo for baskets and making coloured ink. It does not seem to be applied to wool. It is also used as a cosmetic by placing a small portion of the powder in the palm of the hand and moistening it with water; the hands are then rubbed together, producing a lather of a bright gamboge colour, which is applied as required. In DR

Congo *Flemingia grahamiana* is recommended as a cover crop. The tuberous root is said to be edible. In Zimbabwe and Malawi a root decoction is drunk against diarrhoea and dysentery. In India the plant is used in external applications against skin diseases, internally as a purgative and as a medicine for colds.

Properties The fruit powder of *Flemingia grahamiana* contains a dark red to orange-brown resin, an orange-red crystalline substance and small quantities of a yellow crystalline substance. These are flavonoid colorants belonging to the group of chalcones: flemingins A, B and C, homoflemingin and 5-deoxyhomoflemingin. These principles resemble those of kamala (*Mallotus philippinensis* (Lam.) Muell.Arg.), which also are complex chalcones, but not identical. The dye of kamala is also produced by the glands on the fruits and in international trade waras and kamala are often traded together. In dye powder of waras, uncoloured long and simple hairs can be found, whereas in dye powder of kamala short uncoloured stellate hairs are found.

Botany Erect herb or subshrub up to 1.8 m tall with deep growing, sometimes tuberous roots. Leaves alternate, 3-foliolate; stipules deciduous; petiole up to 7 cm long; petiolules c. 3 mm long; leaflets elliptical to obovate, 2–15 cm × 1–8 cm, terminal leaflets largest, pubescent to densely velvety, sparsely to densely covered with small dark red glands. Inflorescence an axillary, densely fasciculate raceme; rachis 1–5 cm long, with imbricate bracts. Flowers bisexual, papilionaceous; pedicel c. 2 mm long; calyx tubular, tube c. 1.5 mm long, lobes 5, linear, 3–6 mm long; corolla yellow-white or pink, standard oblong, 7–8 mm long, wings narrow, slightly shorter than standard, keel about as long as wings; stamens 10, 9 fused and upper one free; ovary superior, hairy, 1-celled, style linear, ending in a small dot-like stigma. Fruit an inflated pod 9–12 mm × 6 mm, yellow-pubescent and also covered with glands secreting reddish globules leaving an orange-red stain on touching, 2-seeded. Seeds globose, c. 1.5 mm in diameter, shiny black.

Flemingia is classified in the tribe *Phaseoleae* and is predominantly an Asiatic genus comprising 30–50 species. From tropical Africa only 2 indigenous species are known. *Flemingia grahamiana* is very variable and based on degree of pubescence and size of leaflets and inflorescence, several varieties have been distinguished. *Flemingia macrophylla* (Willd.) Merr. (originating from tropical Asia) much resembles *Flemingia grahamiana*. It is occasionally cultivated in tropical Africa, e.g. in Côte d'Ivoire, Nigeria and Tanzania. Its fruits can produce the same type of dye (less abundantly), but it is more important as an auxiliary plant grown for shade, cover and mulch.

Ecology *Flemingia grahamiana* is found in open and wooded savanna, sometimes near water in riverine vegetation, on hillsides, termite mounds and along roadsides, in eastern Africa up to 2100 m altitude.

Management *Flemingia grahamiana* can be propagated by seed. The first fruits can be harvested after about one year. After picking the fruits, the shrub is cut down at about 15 cm from ground level. It sprouts again after rain and bears fruits a second time after about six months. The cutting back is repeated every second year until the plant dies. Rain destroys the fruits for commercial purposes; therefore they are only gathered in the dry season. The harvested fruits are first dried (some days in the sun), put in a bag, which then is beaten to loosen the tinctorial powder. Alternatively the fruits are rubbed over a sieve. To prepare the dye, the powder is dissolved in the dye bath with an equal weight of sodium carbonate. When the temperature of the bath reaches 40°C the yarns or textiles to be dyed are put into the bath and the whole is slowly heated to boiling point. To make the colour brighter, the fibre can be washed in slightly acidic water, e.g. made with lemon juice. Beautiful deep yellow or orange colours can be obtained, fast to light and acids, less so to alkaline substances. Those colours were used very frequently in combination with indigo blue in the renowned ikat textiles from Yemen.

Genetic resources and breeding *Flemingia grahamiana* is widely distributed and not in danger of genetic erosion. Germplasm collections are maintained at the Centro Internacional de Agricultura Tropical (CIAT, Cali, Colombia), the Research Institute for Animal Production (Ciawi, Bogor, Indonesia), Australian Tropical Forage Genetic Resource Centre (ATFGRC, CSIRO, Canberra, Australia), and the International Plant Genetic Resources Institute (IPGRI, Bangkok, Thailand), together with those of *Flemingia macrophylla*.

Prospects As source of the waras dye, *Flemingia grahamiana* will remain only locally of importance for dyeing textiles golden-orange or colouring wickerwork. In the current light of the reappraisal of European regulations concerning the toxicity of some synthetic colorants used in the food and cosmetic industries, the traditional applications of waras as a cosmetic and against skin diseases could make it a suitable substitute as a yellow to orange colorant. Its value as a cover crop and as a medicine need more investigation.

Major references Burkill, 1995; Cardon, 2003; Gillett et al., 1971.

Other references Cardillo et al., 1973; CSIR, 1956; Gelfand et al., 1985; Hauman et al., 1954; Irvine, 1961; Mackinder et al., 2001; Mate, Kamabu & Lejoly, 1994; Tournerie, 1986; Mosango, 1999; Williamson, 1955.

Authors P.C.M. Jansen

GRIFFONIA PHYSOCARPA Baill.

Protologue Adansonia 6: 188 (1865).

Family Caesalpiniaceae (Leguminosae – Caesalpinioideae)

Synonyms *Bandeiraea tenuiflora* Benth. (1866).

Origin and geographic distribution *Griffonia physocarpa* occurs in Nigeria, Cameroon, Equatorial Guinea, Gabon, Congo and DR Congo.

Uses A black dye is obtained from the leaves of *Griffonia physocarpa*. Root fibres are collected from the wild and chewed into a cud from which, on drying, a white powder separates, which is used by women as an ornamental face powder. The stems serve as binding material in the construction of huts in DR Congo. In traditional medicine, a decoction of the leaves is taken against stomach troubles and blennorrhoea, and as a wash for children with fever. Macerated leaves are used as a dressing over oedemas and are taken as an aphrodisiac. Ash of leaves is applied externally to treat bone fractures.

Botany Shrub or large liana with glabrous, brown-black branches. Leaves alternate, simple, glabrous; stipules absent; petiole c. 0.5 cm long; blade oblong-elliptical to ovate, 5–15 cm × 3–7 cm, base rounded, apex acuminate, 3(–5)-veined from the base, reticulate venation prominent on both sides. Inflorescence a terminal raceme 5–20 cm long; bracts and bracteoles triangular, 2 mm long, persistent. Flowers bisexual, almost regular, 5-merous; pedicel 0.5–1 cm long; receptacle cylindrical, 2–3 cm × 3 mm, orange; calyx tubular, orange, tube 3–6 mm long, lobes triangular, 2–3 mm long; petals almost equal, claw 3–6 mm long, blade oblanceolate, 1–1.5 cm × 3–4 mm, fleshy, greenish, sparsely pubescent inside; stamens 10, filaments filiform, 2 cm long; ovary superior, c. 4 mm long, stiped, style 1–2 mm long, persistent, stigma small. Fruit an oblique-cylindrical pod 5–7 cm × 3–4 cm, inflated, leathery, stipe up to 2.5 cm long, 1–2-seeded. Seeds orbicular, c. 12 mm in diameter, glabrous.

Griffonia is only found in tropical Africa. It belongs to the tribe *Cercideae* and comprises 4 species.

Ecology *Griffonia physocarpa* occurs in lowland forest, often in secondary forest.

Genetic resources and breeding *Griffonia physocarpa* is widespread and locally common, especially in disturbed forest, and not in danger of genetic erosion.

Prospects *Griffonia physocarpa* will probably remain of local importance only; its dye and medicinal properties need more research before evaluation is possible. The related *Griffonia simplicifolia* (Vahl ex DC.) Baill. contains medicinally very interesting compounds.

Major references Burkill, 1995; Wilczek et al., 1952.

Other references Aubréville, 1968; Aubréville, 1970; Bouquet, 1969; Raponda-Walker & Sillans, 1961.

Authors P.C.M. Jansen

HAEMATOXYLUM CAMPECHIANUM L.

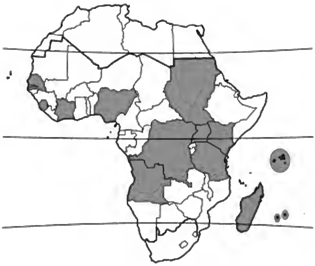
Protologue Sp. pl. 1: 384 (1753).

Family Caesalpiniaceae (Leguminosae – Caesalpinioideae)

Chromosome number $2n = 24$

Vernacular names Logwood, campeche wood, bloodwood tree (En). Arbre à campêche, bois d'Inde, campêchier (Fr). Pau campeche, pau de sangue (Po).

Origin and geographic distribution *Haematoxylum campechianum* is indigenous in Mexico (along the south-eastern coast of the Gulf of Campeche and in Peninsular Yucatan) and Belize. The wood was introduced into Europe as a dyeing substance soon after the Spaniards arrived in Central America, but for many years (from 1581 to 1662) its use in England was prohibited by legislative enactment to protect dyes already in use. After that period British traders started to export the wood from southern Yucatan, where they founded a colony that is now Belize. The representation of two logwood cutters in the national emblem of Belize still reflects the former importance of the trade. The French later established their own source of logwood in Haiti. *Haematoxylum campechianum* has been introduced and widely



Haematoxylum campechianum – planted and naturalized

naturalized since the18th century in the Bahamas, Cuba, Jamaica, Dominican Republic, Puerto Rico and the Antilles. At present it is widely introduced in most tropical countries. It was introduced into Nigeria in the 1890s and has since been cultivated on a limited scale in other parts of continental Africa and in the Indian Ocean islands. It is found naturalized in Madagascar and other Indian Ocean islands.

Uses The main product of *Haematoxylum campechianum* is the heartwood, which is the logwood of commerce. The principal interest lies in the dye substance extracted from this wood: the chemical haematoxylin, a sweet, colourless crystal. It gives the wood its characteristic reddish colours by the combined action of oxygen from the air and alkaline bases present in the wood. Dark purple scales of haematein are formed by the action of ammonia and oxygen from the air during processing of the wood. Haematein is the colouring agent and is used commercially for dyeing wool, silk, cotton, fur, leather, bone and certain synthetic fibres (e.g. nylon and rayon), using chromium mordants to obtain purple and black. It has a fair degree of fastness and good penetration. By selection of different mordants, subtle colour tones ranging through lilac, violet, blue, grey to black can be produced and other shades and colours can be achieved by admixture of other dyes. Haematein is much used in ink, both for writing and painting. In an acid environment it gives a red colour that has been used to adulterate wine. Haematoxylin is the most important natural dye in histochemistry. Heidenhain's iron haematoxylin method has been traditionally recommended for staining intestinal protozoa. In this method haematein reacts with ferric ammonium sulphate to produce ferric lake (iron haematoxylin) which regressively stains mitotic figures in protozoa. Haematein is a standard histological stain mostly used in combination with eosin, whereby haematein shows up cell nuclei and eosin the protoplasm.

Being rich in tannins, decoctions of the bark are used in Senegal and Mauritius against diarrhoea, and an infusion of the flowers is used against bronchial problems. Extracts have been used in traditional medicine as an astringent, anti-inflammatory agent and to treat gastric disorders.

Haematoxylum campechianum is also an ornamental with evergreen showy foliage and yellow, sweet-scented flowers. The plant is thorny and makes an impenetrable but attractive hedge. In the islands of the Indian Ocean, particularly Rodrigues, the tree is grown and highly prized by bee keepers as its flowers impart a distinctive flavour and fragrance to the honey produced locally. Logwood has been used as timber (e.g. in Senegal for furniture and in India for inlaid veneer), but this use is limited because of the usually irregular shape of the trunk. It is also an acceptable firewood.

Production and international trade The annual export of logwood peaked in the latter half of the19th century at about 100,000 t. In 1880 the imports of logwood into the United Kingdom stood at about 70,000 t. Nowadays, logwood cutting is only a minor industry and to reduce costs logwood is exported mainly as powdered extracts. The best qualities of logwood come from Campeche (Mexico), but only in small quantities; larger amounts of good-quality logwood are exported from the larger Caribbean islands (Jamaica, Haiti, Dominican Republic). In the course of the 1990s the total annual logwood trade was no more than 600 t of extracts, corresponding to about 2500 t of source wood. The major importers are Western Europe, North America and Japan. France and Switzerland supply many consuming countries through re-export trade. Prices have fluctuated enormously over the years.

Properties The heartwood of *Haematoxylum campechianum* contains approximately 10% haematoxylin and is pale coloured but acquires a bright reddish colour with age or on exposure to air. Haematoxylin crystals are readily soluble in hot water and alcohol, sparingly in cold water. The action of ammonia and oxygen from the air causes dark purple scales of haematein (haematoxein) to form, often observable as the fine greenish hue on logwood chips. The action of diluted acids changes the dark purple colour to bright red. Mordants are necessary to dye textiles with haematein and different mordants give very different colours: copper sulphate gives a purplish blue, zinc sulphate dark purple, nitro-muriate of gold orange, muriate of quicksilver orange-red, muriate of antimony crimson, lead acetate blue, arsenate of potash deep yellow, nitrate of barytes brownish purple and muriate of barytes reddish purple.

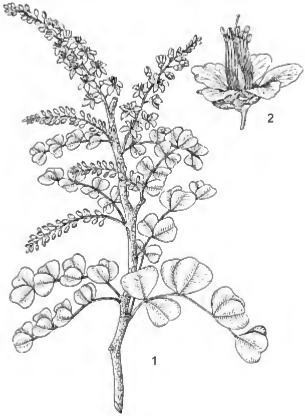
Haematoxylin has the unique capacity to distinctively dye crystals of stereoisomeric compounds, making their difference visible to the naked eye. Haematoxylin exhibited dose-dependent anti-inflammatory activities in tests with rats and chicken embryos. It showed a considerable effectiveness against acute inflammation, but little activity against chronic inflammation.

The heartwood is very hard and heavy, with an air-dry density of 950–1085 kg/m^3. The grain is interlocked, texture coarse but fairly even. The wood has an agreeable odour resembling violets and a sweet astringent taste. It is brittle and difficult to work by hand, but finished to a smooth surface it takes a high polish. It is durable in contact with the ground and in exposed conditions. The sapwood ring is thin, white or yellow and is of little value as it does not contain haematoxylin. Several gallotannins and flavonoids have been isolated from the leaves.

Adulterations and substitutes The wood of *Caesalpinia* species contains brazilin, which is a compound also used as a red dye and related to haematoxylin. Brazilin has anti-inflammatory properties similar to haematoxylin.

In the 1970s a shortage of haematoxylin in the world market led to a search for alternative dyes in histology. Celestine blue B and Mordant blue 3 were reasonable alternatives, but did not have the wide variety of uses of haematoxylin.

Description Shrub or small, bushy tree up to 15 m tall, often thorny; trunk irregularly fluted and contorted, up to 3 m long and up to 60 cm in diameter; bark grey to brown, rather smooth, peeling into flakes; branches long, straight. Leaves alternate, distichous or fascicled on very short branches, paripinnate; stipules c. 2 mm long, caducous; petiole up to 1 cm long; leaflets in 2–4 pairs, obcordate or obovate, 1–3.5 cm × 0.5–2.5 cm, cuneate at base, emarginate at apex, glabrous and closely veined. Inflorescence an axillary raceme 3–10(–20) cm long. Flowers bisexual, almost regular, 5-merous, sweet-scented; pedicel c. 5 mm long; sepals oblong, 4–5 mm long; petals narrowly obovate, 5–7 mm long, dull yellow; stamens 10, free; ovary superior, sessile, glabrous, 1-celled, style slender, stigma small. Fruit a lanceolate to narrowly elliptical, flattened pod 3–5.5 cm long, pointed at both ends, dehiscent along the median of the sides, 1–2-seeded. Seeds elongated, c. 1 cm long, flat.



Haematoxylum campechianum – 1, flowering branch; 2, flower.
Source: PROSEA

Other botanical information Two other *Haematoxylum* species are known: *Haematoxylum brasiletto* H.Karst. (peachwood) from tropical America, the wood of which is also used as source of a red dye (brazilin) considered inferior to the dye of logwood, and *Haematoxylum dinteri* (Harms) Harms, a shrub up to 2 m tall, endemic in Namibia in rocky crevices and sandy river beds.

Growth and development *Haematoxylum campechianum* grows slowly but cultivation is easy. With favourable growing conditions, the tree can attain harvestable size in about 10 years, and sometimes harvesting can even start when 8 years old.

Ecology *Haematoxylum campechianum* is a lowland species which can grow under different conditions. It can withstand dry conditions, but in Central America it grows best in flat marshy areas often inundated by rivers, occasionally forming almost pure stands. In the West Indies, the best wood is produced in interior valleys and moist coves in the lower slopes of hills. In Jamaica logwood is common on exposed limestone hillsides in dry secondary thickets. In Madagascar and the Mascarene islands it occurs naturalized in disturbed vegetation and roadsides in dry regions. Logwood grows on almost any soil, but prefers light soils with some humus.

Propagation and planting *Haematoxylum campechianum* can be propagated by cuttings and seed.

Management Apart from weed control during the establishment phase, logwood requires minimal attention. In the early years of a plantation, annual or short perennial understorey crops can be grown.

Harvesting In Central America logwood is mostly collected from the wild. The older the tree, the richer the colour of the wood. In trade, freshly cut wood with non-oxidized haematoxylin is preferred. Commercial production of *Haematoxylum campechianum* comes from plantations (e.g. in Jamaica), where the trees can be pruned to produce a straight clean bole. Felling is normally done at 10 years old. The wood, deprived of its bark and sapwood, is transported to the factory or market in the form of large blocks and billets 1–2.5 m long.

Handling after harvest The pieces of wood are reduced to very small chips, which are boiled in hot water to extract the dye. The resulting orange-red solution turns yellow and later black upon cooling. Evaporation of the liquid leaves behind a powder, often called crystals. The crystals are graded according to the degree of oxidation of haematoxylin to haematein, usually over a range of 15% to 100%. An 80% grade contains 80% haematein and 20% haematoxylin.

Genetic resources Although there are no specific data on the genetic variability of *Haematoxylum campechianum*, the wide variation in habitat and the existence of plants lacking haematoxylin (called 'bastard logwood') suggest considerable variation within the species.

Breeding Breeding objectives are selection of superior genotypes that can be used for propagation, e.g. plants with high dye content, good growth performance and good climatic adaptation.

Prospects In major dyeing applications, logwood has increasingly been replaced by synthetics because of periodic supply problems and related price rises. However, the special qualities of the dye remain highly regarded, especially in histology, and the threat of complete replacements by synthetics is not yet evident. Considering the recent renewed interest worldwide in natural colorants, it may be assumed that the demand for logwood is likely to increase. Experiments on a larger scale cultivation of logwood in tropical Africa, e.g. in agroforestry systems, might be worthwhile.

Major references Burkill, 1995; Cardon, 2003; du Puy et al., 2002; Ferreira, 2003; Green, 1995; Kahr, Lovell & Anand Subramony, 1998; McJunkin, 1991; Norton, 1996; Seegeler, 1991.

Other references Armstrong, 1992; Gurib-Fakim, Guého & Bissoondoyal, 1995; Hikino et al., 1977; Polhill, 1990; Rastogi & Mehrotra, 1998.

Sources of illustration Seegeler, 1991.

Authors A. Gurib-Fakim

Based on PROSEA 3: Dye and tannin-producing plants.

IMPATIENS TINCTORIA A.Rich.

Protologue Tent. fl. abyss. 1: 120 (1847).

Family Balsaminaceae

Synonyms *Impatiens prainiana* Gilg (1909).

Vernacular names Balsamine (En). Balsamine (Fr).

Origin and geographic distribution *Impatiens tinctoria* is found in south-eastern Sudan, Eritrea, Ethiopia, western and southern Kenya, Uganda, DR Congo, southern Tanzania and northern Malawi. It is cultivated worldwide as an ornamental.

Uses In Ethiopia women chop or mash the inside of the tubers of *Impatiens tinctoria* ('ensolella') into a paste to dye the palms and nails of the hands and feet a dark reddish colour. It is considered a beauty treatment similar to that of henna and it helps to control fungal infections and it toughens the skin. The tubers are also used to dye cloth. The juice of pounded roots is one of the ingredients for a red ink. Medicinally, a root decoction is drunk against abdominal pains and as a purgative. The stem is chewed to treat mouth and throat diseases.

Horses and mules graze the plant. *Impatiens tinctoria* is cultivated for its striking flowers as an indoor and outdoor ornamental in tropical and temperate regions.

Properties The flowers and leaves of another species, *Impatiens balsamina* L. (garden balsam, native of India and parts of mainland South-East Asia but widely cultivated as an ornamental, also in Africa) are used to prepare a red dye to colour the nails and are used as a substitute for henna because they contain the same dyeing agents lawsone and derivatives, as well as anthocyans and flavonoids such as kaempferol, quercetin and a rhamnocitrin glycoside. Although the dye components of *Impatiens tinctoria* and many other species (e.g. *Impatiens rothii* Hook.f.), also used to dye the skin red, have not been thoroughly investigated, they all contain naphtoquinone derivates close to lawsone and might be used as substitutes for henna. Medicinally, lawsone shows antifungal activity and is active against fungi causing ringworm, athlete's foot (tinea pedis).

Botany Erect, glabrous, perennial herb up to 2 m tall, with a succulent hollow stem and a large tuberous rootstock up to 30 cm × 10 cm. Leaves arranged spirally, simple; stipules absent; petiole up to 9 cm long, sometimes bearing glands near the top; blade oblong-lanceolate to broadly ovate, 7–32 cm × 2.5–10 cm, base cuneate, apex usually acuminate, margins crenate to serrate, lateral veins in 7–14 pairs. Inflorescence an axillary 3–9-flowered raceme; peduncle up to 30 cm long. Flowers bisexual, zygomorphic, 5-merous, fragrant, white but lower petals often spotted pink or purple near base; pedicel up to 4 cm long; lateral sepals 4, ovate or oblong, 6–10 mm × 4–7 mm, lower sepal funnel-shaped, gradually constricted into a 3–13 cm long filiform spur; dorsal petal hood-like, 17–22 mm × 10–14 mm, crested dorsally, lateral petals 4, united in pairs, upper one of each pair small, 6–15 mm × 2–5 mm, lower one large, 16–50 mm × 16–46 mm; stamens 5, connate in a ring; ovary superior, 5-celled, style very short. Fruit a cylindrical, 5-valved, fleshy, explosively dehiscent capsule up to 4 cm long, many-seeded. Seeds ovoid, glabrous.

Impatiens is a large genus comprising more than 1000 species, and occurs in tropical and subtropical regions of Africa, Asia and Central America, as well as in temperate regions of the northern hemisphere, but it is absent in South America and Australia. In Africa more than 100 species occur. *Impatiens tinctoria* is variable; it has been subdivided into 5 subspecies, mainly based on differences in leaf, flower and spur size.

In Ethiopia, the tubers of *Impatiens rothii* ('girshirit') are also used for a dark reddish dye.

Ecology *Impatiens tinctoria* usually occurs in damp, shady localities, in upland rain forest, forest fringes and gullies, along streams and on shady banks, usually at 700–3600 m altitude.

Management Although *Impatiens tinctoria* is cultivated for its tubers in Ethiopia (southern Tigray), no cultivation details are known. As an ornamental, it is easily propagated by cuttings, and can be grown indoor in pots and outside, provided it is protected against frost. Red spider mite and aphids can be problematic pests.

For dyeing the skin, tubers are washed and sometimes peeled, chopped and left steeping for at least 12 hours. Then they are heated, mashed and the paste is applied to palms and nails of hands only (for young girls) or to hands and feet (adult women). It can also be put in leaves, wrapped and tied around the hands and feet for 6–8 hours to get a more lasting dye. To dye cloth, salt and oil are added to the dye bath where chopped tubers are boiling before plunging the cloth. A red ink is obtained by mixing the juices of the tubers of *Impatiens tinctoria* ('ensolella'), *Impatiens rothii* ('girshirit') and *Rubia cordifolia* L. ('minchier'), and the bark of *Osyris quadripartita* Salzm. ex Decne. ('keret'), then letting the liquid mixture thicken in the sun.

Genetic resources and breeding *Impatiens tinctoria* is widespread in Africa and does not seem to be in danger of genetic erosion. Nevertheless, because of its great diversity, collection of germplasm is strongly recommended.

Prospects As a dye, *Impatiens tinctoria* most probably will remain only of local importance in Ethiopia. Its importance as an easy-to-grow, fragrant, large ornamental will remain considerable.

Major references Grey-Wilson, 1980; Kokwaro, 1993; Lemordant, 1971; Mesfin Tadesse, 2000; Tournerie, 1986.

Other references Grant-Downton, 1992; Grey-Wilson, 1982; Launert, 1963; Phuphathanaphong, 1991; Rosna Mat Taha, 2001; Westphal, 1975; Wilczek & Schulze, 1960.

Authors P.C.M. Jansen

INDIGOFERA ARRECTA Hochst. ex A.Rich.

Protologue Tent. fl. abyss. 1: 184 (1847).

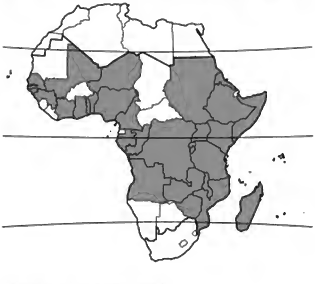
Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Chromosome number $2n = 16$

Vernacular names Natal indigo, Bengal indigo, Java indigo (En). Indigotier chessé, indigotier (Fr). Indigueiro, anileira (Po). Mnili (Sw).

Origin and geographic distribution Natal indigo originates from Africa. It occurs almost throughout tropical Africa, and also in northern and eastern South Africa, Swaziland and southern Arabia. Its range has probably been extended by its cultivation for indigo and subsequent naturalization. It is widely planted in India and south-eastern Asia.

The use of indigo extracted from *Indigofera* species has a long history. Indigo plants and the dyestuff were already mentioned in the oldest Sanskrit records. The blue dye used for textiles of Egyptian mummies may, in some cases, come from an *Indigofera* species but woad (*Isatis tinctoria* L.) is another indigo-blue producing plant known to ancient Egyptians. The most ancient archaeological textiles discovered in West Africa, the 'Tellem textiles', were found in funeral caves in the Bandiagara cliff in the Dogon area of Mali. Some of them date back to the 11th or 12th centuries and already include stripes, checks and tie-and-dye patterns done with indigo from *Indigofera* or *Philenoptera* species. An early description of the local extraction process of indigo from an *Indigofera* species in Guinea was left by the Portuguese explorer André Alvares de Almada in 1566. In Africa Natal indigo has been the most important species for the production of indigo since the beginning of the 20th century.



Indigofera arrecta – wild

Uses Leafy twigs of *Indigofera arrecta* and some closely related *Indigofera* species are the main sources of the indigo dye used since very ancient times for dyeing textiles blue. The leaves and twigs do not contain indigo but colourless precursors that must be extracted and processed to produce the indigo dye. Because of its fascinating deep blue colour, its great colour fastness to light and the wide range of colours obtained by combining it with other natural dyes, indigo has been called 'the king of dyes'. No other dye plants have had such a prominent place in as many civilizations as *Indigofera* species. In western Africa indigo is by far the most important dye of plant origin. It plays an important role in traditional cultures of many people, whether only wearers of indigo-dyed textiles like the Tuareg in the Sahara and Sahel region (Niger, Mali), or renowned indigo dyers, among which the Soninke (Sarakole) and Wolof in Senegal, the Marka women of the Djenné region in Mali, the Dyula and Baule in Côte d'Ivoire, the Yoruba and Hausa in Nigeria and the Bamoum and Bamileke in Cameroon. This part of the world is a major centre of textile decoration techniques based on the concept of 'resist-dyeing' and linked with indigo dyeing: intricate patterns are made on the cloth that will resist being dyed. This is done by tying, sewing or plaiting parts of the cloth or by covering them with starch pastes or wax. The piece of cloth is then plunged into the indigo vat to dye the untreated parts. After the resist threads or pastes have been removed, white patterns on a blue ground appear. Light blue patterns on a blue-black ground are formed if a last indigo bath is given after undoing the resist. In Madagascar too, indigo dyeing is very important, for instance in raffia ikats, beautiful textiles in which the 'resist' patterns are formed by tying parts of the warp yarns with thick threads before dyeing them with indigo and putting them onto the weaving loom, which again creates white designs on a blue ground. However, the use of natural indigo is rapidly declining and nowadays, synthetic indigo is almost exclusively used, not only in industrialized processes but also at craft level.

Indigofera arrecta is grown as a cover crop and for green manure, especially in tea, coffee and rubber plantations. It gives shade and protection, suppresses weeds and improves the soil. The residue remaining after indigo extraction is also applied as manure. In Malawi the young

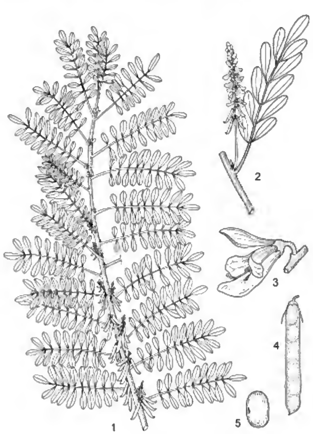
leaves are eaten as a vegetable. The plants are grazed by all stock.
Numerous applications in traditional medicine have been reported: leaves and roots are used externally to treat itching and in an infusion or decoction as an antispasmodic, sedative, stomachic, febrifuge, vermifuge, abortive, diuretic and purgative, e.g. to treat gum infections, snakebites, gonorrhoea, epilepsy and jaundice; the fruits and seeds are used to treat ophthalmia. In Ghana an aqueous extract of leaves from immature shoots is administered orally to patients with diabetes mellitus. A medicine for the management of peptic ulcer and methods of its preparation and use have been patented. In several regions in Africa it is believed that the indigo in clothes prevents skin complaints. In East Africa the twigs are used for cleaning teeth.

Production and international trade Already in antiquity indigo was traded from India to the Mediterranean region, but this became more important during the Middle Ages. Large-scale cultivation of *Indigofera* started in the 16th century in India and south-eastern Asia. Later, large plantations were established in Central America and the southern United States. The large-scale export of indigo from Asia to Europe started in about 1600 and had to compete with dye from woad which was cultivated mainly in France, Italy, Germany and Great Britain. By the end of the 17th century, indigo had almost completely replaced woad. Synthetic indigo, which came into commercial production in 1897, proved catastrophic to the production of natural indigo, and by 1914 only 4% of the total world production was of plant origin. Then followed a period in which synthetic indigo lost some of its importance due to competition from new synthetic dyes, but the ever growing popularity of blue jeans enormously contributed to a revival of interest in indigo. At present, the crop is still cultivated for dye production on a small scale in India and in some parts of Africa, southern Arabia (Yemen), Central America and Indonesia. The most important present-day centre of indigo production from *Indigofera* is probably the northern part of Karnataka state in India. In India, annual production of *Indigofera* dye gradually decreased from 3000 t from 600,000 ha in 1890, to 50 t from 4000 ha in the 1950s, to an annual export fluctuating between 2 t and 20 t in the 1990s.

Properties *Indigofera* plants contain the glucoside indican. After soaking the plants in water, enzymic hydrolysis transforms indican into indoxyl and glucose. Indigotin (often also called indigo or indigo-blue) formation results from the grouping of two molecules of indoxyl in the presence of oxygen. Indigotin is insoluble in water, so to dye textiles it must be reduced to a soluble form (colourless 'leuco' indigo or indigo-white) by a fermentation process under alkaline conditions or by a chemical reducing agent such as sodium dithionite. Subsequent oxidation by airing of the textile after its removal from the dye bath, results in the regeneration of indigotin and fixation of the blue colour onto the textile. Natural indigo can contain varying proportions of a chemically related red dye called indirubin and of the minor isomeric compounds isoindirubin (red) and isoindigo (brown).
The leaves of *Indigofera arrecta* contain 4.5% N, 0.02% P_2O_5, 1.95% K_2O and 4.5% CaO. Whole plants of Natal indigo showed good palatability in sheep.
An aqueous extract prevented the development of hyperglycaemia in genetically obese diabetic mice. In tests with rats, an intraperitoneal administration of a hot water extract of dried leaves decreased the plasma glucose levels of fasting normoglycaemic rats, but did not prevent the rise in plasma glucose after an oral glucose load. It was suggested that the extract is insulinotropic and may require functional β-cells to be active. In tests with healthy, non-diabetic, young adult male volunteers in Ghana, an extract of Natal indigo increased the erythrocyte sedimentation rate and decreased lymphocyte concentration in the blood. It did not alter the mean systolic and diastolic pressures, nor did it change fasting blood glucose, whereas serum marker enzymes and metabolites for hepatic and renal functions remained normal. These data suggest that the species may not have overt toxic reactions but could affect the immune status of users. The extract also showed no acute and subchronic toxic effects in tests with mice.

Adulterations and substitutes Several other, often unrelated, plant species are sources of indigo dyes. Examples include woad from Europe, *Polygonum tinctorium* Aiton from China, Korea and Japan, Assam indigo (*Strobilanthes cusia* (Nees) Kuntze) from Indo-China and Thailand and *Marsdenia tinctoria* R.Br. from tropical Asia. In West Africa, gara (*Philenoptera cyanescens* (Schumach. & Thonn.) Roberty) and Gambian indigo (*Philenoptera laxiflora* (Guill. & Perry) Roberty) are important sources of indigo. They also contain indican and are often combined with indigo from *Indigofera* species in traditional indigo dyeing processes. Other natural sources of indigo are a mutant of the fungus *Schizophyllum commune* and the purple snail *Hexaplex trunculus,* which mostly contains precursors of indigo and only minor proportions of the bromine derivatives of indigo of which the famous Tyrian purple dye of antiquity was composed. The most important substitute of natural indigo, however, is the synthetic industrial product.

Description Annual to perennial herb or subshrub up to 2(–3) m tall: stem erect, copiously branched, slightly ridged, covered with appressed, whitish or brownish, 2-branched hairs. Leaves arranged spirally, imparipinnate: stipules subulate to bristle-like, 2–9 mm long; petiole up to 1.5 cm long, thickened at base, rachis up to 6 cm long; stipels subulate, up to 1 mm long; petiolules c. 1 mm long; leaflets 7–21, narrowly elliptical-oblong, up to 20 mm × 7 mm, usually glabrous above, appressed hairy below. Inflorescence a usually sessile, many-flowered axillary raceme up to 5 cm long but usually much shorter; bracts lanceolate, c. 1 mm long, caducous. Flowers bisexual, papilionaceous; pedicel c. 1 mm long, strongly reflexed in fruit; calyx c. 1.5 mm long, the tube about as long as the 5 triangular lobes, brownish appressed hairy; corolla c. 5 mm long, pinkish or reddish, standard obovate, narrowed gradually to the base, wings with very short claws, keel laterally spurred; stamens 10, 3–4 mm long, upper one free, the other 9 united into a tube; ovary superior, 1-celled, with long style. Fruit a linear pod 12–17 mm long and c. 2 mm wide, straight, slightly tetragonal, brown when ripe, 4–6-seeded with slight constrictions between the seeds. Seeds shortly oblong, c. 2 mm × 1.5 mm, rhombic in cross-section. Seedling with epigeal germination; cotyledons thick, short-lasting.



Indigofera arrecta – 1, flowering and fruiting branch; 2, part of stem with leaf and inflorescence; 3, flower; 4, fruit; 5, seed.
Source: PROTA

Other botanical information *Indigofera* is a very large genus comprising approximately 700 species and is distributed throughout the tropics and subtropics of Africa, Asia and the Americas. Africa and the southern Himalayas are richest in species. Over 300 species have been recorded for tropical Africa.

For indigo production several *Indigofera* species are used but there are 3 closely related major ones: *Indigofera arrecta, Indigofera tinctoria* L., which probably originates from tropical Asia but is now distributed pantropically, and *Indigofera suffruticosa* Mill., originating from tropical America and now locally cultivated elsewhere in the tropics, including Africa and Madagascar but not in tropical East Africa. The origin and identity of *Indigofera* plants cultivated for dye production is often obscure as a result of introduction, selection and the close affinity of species. *Indigofera arrecta* is sometimes difficult to separate from *Indigofera tinctoria*. The latter usually differs in its larger and less numerous leaflets and longer fruits containing more seeds. In East Africa, but not in West Africa, *Indigofera arrecta* generally occurs at higher altitudes (1000–2000 m) than *Indigofera tinctoria* (below 1000 m). *Indigofera suffruticosa* differs from *Indigofera arrecta* by its short, 10–15 mm long, red-brown pods. Intermediate specimens between these 3 species have been found, possibly of hybrid origin.

Growth and development Seeds germinate in about 4 days. Plants may start to flower 3 months after sowing. Like many other leguminous plants, *Indigofera arrecta* forms root nodules with nitrogen-fixing capacity with e.g. *Rhizobium indigoferae*. The total lifespan for dye crops is 2–3 years when grown as a ratoon crop.

Ecology *Indigofera arrecta* occurs in open deciduous forest, upland evergreen bushland, often in forest margins, and secondary regrowth. It occurs at 200–2700 m altitude, in regions with an annual rainfall of 400–1800 mm. The plant is deep-rooting and withstands drought well. When used as a cover crop, Natal indigo can only be grown in gardens or plantations with little or no shade. An established crop can withstand very wet soil for up to 2 months.

Propagation and planting Propagation is usually by seed. Seed yields of 675–1200 kg/ha have been reported for India. The seeds have a hard seed coat and soaking overnight in water or scarification with sulphuric acid is needed before sowing. Fields are prepared by hoeing or by one or two ploughings after showers followed by light harrowing before and after broadcast sowing. Sowing in a nursery and transplanting into the field may also be practised.

Management The crop normally requires little attention after sowing. Weeding is done when needed. As a cover crop, Natal indigo is slashed at regular intervals. Production of seed is usually poor in plants that have been cut. Seed production therefore requires plants to be grown specifically for this purpose.

Diseases and pests Natal indigo is attacked by *Ralstonia solanacearum* (synonym: *Bacillus solanacearum*), several fungi and nematodes.

Harvesting Branches are harvested when the plants are 4–5 months old and have formed a closed stand, usually at the flowering stage. The plants can be cut again 2–4 months later. Up to 3 harvests are possible per year when it is grown as a ratoon crop.

Yield The dye yield from Natal indigo is higher than from any other *Indigofera* species. Annual yields of 22–100 t green matter per ha have been reported in India; the recorded output of indigo cake is 135–325 kg/ha per year.

Handling after harvest In small-scale cultivation in Africa, harvested branches are often pounded to a soft pulp and made into balls, which are sold on the market after drying. This is the method described by André Alvares de Almada in 1566 and in all early reports. In large-scale cultivation the branches are put in a water containing tank or pit immediately after harvesting. After some hours of fermentation, during which enzymic hydrolysis leads to the formation of indoxyl, the liquid is transferred to another pit or tank and stirred continuously for several hours to stimulate oxidation of the indoxyl to indigotin. Afterwards, the solution is left to rest and the insoluble indigotin settles down to the bottom as a bluish sludge. The water is drained off, and after the indigotin has been washed to get rid of impurities, it is pressed, dried and usually cut into cubes which can be packed and sold.

To dye textiles, indigotin must be reduced to a soluble form under alkaline conditions. In traditional processes (indigo vats), the reduction of indigotin into soluble indigo-white is achieved through a bacterial fermentation. The reducing bacteria are obtained in the bath by adding vegetable matter such as the crushed indigo balls, or, when indigo powder is used, crushed balls of *Philenoptera* leaves, or, according to some recipes, molasses, coconut-milk, banana or guava leaves. An alkaline pH of around 8.2 is adequate and is maintained by adding a potash lye prepared from the ashes of different calcinated plants specially selected for this purpose in each region (among the Marka women of Mali the most appreciated species are *Adansonia digitata* L. (baobab), *Anogeissus leiocarpa* (DC.) Guill. & Perr., *Balanites aegyptiaca* (L.) Delile, *Bauhinia reticulata* DC. and *Faidherbia albida* (Delile) A.Chev.). Less often, the bath is made alkaline by adding freshly slaked lime. In the industrial process, an alkaline solution of sodium dithionite is used for reducing indigo to indigo-white. This polluting chemical process has now been adopted by most craft dyers. Often a gum (e.g. from *Acacia senegal* (L.) Willd. or *Anogeissus leiocarpa* (DC.) Guill. & Perr.) is added to make the coloured textile more durable and windproof. After the textile has been dipped into the solution of indigo-white, it turns blue when exposed to the air. Several dips are needed to impart a dark blue colour to the textile and especially to cotton fabrics, each dip followed by exposure to the air for some time. In Africa very often dyeing is followed by calendering, a finishing process that consists of beating indigo powder onto the surface of the cloth using heavy mallets to give the textile an iridescent, metallic shine, like on the Tuaregs' veils. This finish has both aesthetic and medicinal purposes: since the indigo powder is not fixed durably onto the cloth it discharges onto the skin of the people who wear such cloth and acts as a disinfectant and cicatrising drug. Textiles dyed with indigo are very colour-fast to light and washing, less so to rubbing.

Genetic resources *Indigofera arrecta* is widespread in Africa and is unlikely to be liable to genetic erosion. The share of related species in the gene pool of plants cultivated as

Indigofera arrecta is unclear, as is the influence of these species and of cultivated plants on the genetic variation of wild-growing *Indigofera arrecta*.

Several germplasm collections of *Indigofera* exist, the largest being maintained at CSIRO, St. Lucia, Queensland, Australia (365 accessions) and CIAT, Cali, Colombia (250 accessions). In Africa, collections are present in Ethiopia (ILRI, Addis Ababa, 60 accessions), Kenya (e.g. National Genebank of Kenya, Kikuyu (40 accessions) and in South Africa (Pretoria).

Prospects In spite of its cultural importance, the use of indigo of vegetable origin has almost disappeared, being replaced by synthetic indigo. In West Africa colourful printed textiles, which have a long history in local fashions, are now the most important type of textiles worn by the majority of people and they are mainly imported from Asia or Europe. In recent years, with worldwide increasing concern for sustainability and the demand from consumers for natural products, there has been a revival of interest in natural indigo. Much research still has to be done to optimise indigo production from the most promising plants. Natal indigo is a multipurpose species; it is very useful as a forage and as a cover crop and green manure in agriculture, and its medicinal properties deserve more research.

Major references Balfour-Paul, 1998; Burkill, 1995; Cardon, 2003; Duke, 1981; Gillett et al., 1971; Green, 1995; Lemmens & Wessel-Riemens, 1991; Oei (Editor), 1985; Schrire, 1998; Sittie & Nyarko, 1998.

Other references Addy, Addo & Nyarko, 1992; Boser-Sarivaxévanis, 1969; de Melo, 1947; du Puy et al., 2002; Gillett, 1958; Hepper, 1958; Miège, 1992; Monteil, 1971; Nyarko et al., 1999; Nyarko, Sittie & Addy, 1993; Picton & Mack, 1979; Sudibyo Supardi & Hurip Pratomo, 2003.

Sources of illustration Hepper, 1958; Troupin, 1982.

Authors R.H.M.J. Lemmens & D. Cardon

INDIGOFERA COERULEA Roxb.

Protologue Fl. ind. ed. 1832, 3: 377 (1832).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Chromosome number $2n = 16$

Synonyms *Indigofera articulata* auct. non Gouan.

Vernacular names Indigo (En). Indigotier (Fr). Anileira (Po). Mnili (Sw).

Origin and geographic distribution In tropical Africa *Indigofera coerulea* occurs in the Sahel zone from Mali east to Somalia, and south to Kenya and Uganda. It is also found from Algeria though Arabia to India and Sri Lanka and it has been introduced in Mauritius. *Indigofera coerulea* was formerly much cultivated for indigo in drier areas and its wide distribution has possibly been influenced by this fact.

Uses All aboveground parts of *Indigofera coerulea* are a source of indigo, which is used to dye textiles blue. In the Ogaden area of Ethiopia dried, ground up leaves and roots are used as a wound dressing. An extract of the leaves is drunk against constipation and applied as a wash against infected eyes.

Properties *Indigofera* plants contain the glucoside indican. After soaking the plants in water, enzymic hydrolysis transforms indican into indoxyl and glucose. Indoxyl can be oxidized to indigotin (indigo-blue). Indigotin is insoluble in water, so to dye textile it must be reduced to a soluble form by a chemical or fermentation process under alkaline conditions. Textile fibres dipped in the vat become impregnated with the soluble and colourless 'leuco'-form of the dye (indigo-white) and subsequent oxidation ('airing') results in the precipitation of the blue indigotin on the textile. Natural indigo also contains varying proportions of a chemically related red dye called indirubin.

Botany Herb up to 1 m tall, with slightly angled stem, densely covered with appressed, silvery hairs. Leaves alternate, pinnately compound with 5–9(–11) leaflets; stipules triangular-subulate, 1–3 mm long; petiole up to 2 cm long, rachis 6 cm; petiolules c. 2 mm long; leaflets oblong-obovate, up to 32 mm × 23 mm, densely hairy. Inflorescence an axillary, sessile, many-flowered raceme up to 4 cm long. Flowers bisexual, papilionaceous; pedicel c. 1 mm long, strongly reflexed after flowering; calyx tubular, 5-lobed, 1.5 mm long, densely white or golden-brown hairy; corolla golden-brown hairy outside; stamens 10, upper one free, the other 9 united, 3–3.5 mm long; ovary superior, 1-celled, style long. Fruit an indehiscent, curved, hairy, cylindrical pod c. 15 mm × 2–3 mm × 1.5–2 mm, with 3–4 oblong-elliptical segments, upper suture about 1.5 mm wide, silvery hairy when young, brown when old, 3–4-seeded. Seeds ellipsoid, smooth.

Indigofera is a very large genus, comprising about 700 species pantropically, with more than 300 in tropical Africa. Based on the hairiness of the leaflets, 2 varieties of *Indigofera coerulea* have been distinguished: var. *coerulea* with upper side of the leaflets glabrous and var. *occidentalis* J.B.Gillett & Ali with upper side of the leaflets hairy. *Indigofera coerulea* has been much confused with *Indigofera articulata* Gouan from Egypt and Arabia, which has 3–5 leaflets, globular pod segments and a narrow pod suture.

Ecology *Indigofera coerulea* grows in subdesert and open *Acacia-Commiphora* bushland, at 200–1250 m altitude, in areas with an annual rainfall of 200–250 mm.

Management Although *Indigofera coerulea* has been cultivated, details about cultivation methods are not known. It is supposed that cultivation will be more or less similar to that of, for example, *Indigofera arrecta* Hochst. ex A.Rich.

Genetic resources and breeding *Indigofera coerulea* is widespread and not in danger of genetic erosion.

Prospects The use of natural indigo as a dye has almost disappeared and has been largely replaced by synthetic indigo. The revival of interest in natural dyes might also involve *Indigofera coerulea*, which now is only of marginal importance as a source of blue dye in dry areas.

Major references Burkill, 1995; Cardon, 2003; Gillett et al., 1971.

Other references Gillett, 1958; Lemmens & Wessel-Riemens, 1991; Neuwinger, 2000.

Authors P.C.M. Jansen

INDIGOFERA LONGIRACEMOSA Boivin ex Baill.

Protologue Bull. Mens. Soc. Linn. Paris 1: 399 (1883).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Vernacular names Indigo (En). Indigotier (Fr). Anileira (Po). Mnili (Sw).

Origin and geographic distribution *Indigofera longiracemosa* is indigenous to coastal areas of Kenya, Tanzania, Comoros, Madagascar and southern India. Occasionally it has been cultivated in Madagascar and introduced elsewhere, e.g. in Indonesia.

Uses In its distribution area, *Indigofera longiracemosa* is a minor source of indigo, used to dye textiles blue. Historically it is perhaps most important in Madagascar, where the dye of *Indigofera longiracemosa* is considered superior to the dyes of *Indigofera tinctoria* L. or *Indigofera suffruticosa* Mill. The dye was extracted both at domestic and industrial scale. Traditional indigo-dyeing techniques in Madagascar mainly used local *Indigofera* leaves both fresh and in a composted state. Indigo dyeing was still important there until recent years, especially for the magnificent raffia textiles called 'lay masaka', which are still produced e.g. in Kandreho village in the former Sakalava kingdom near Maevatanana. These textiles have ornate designs made with an 'ikat' technique in which parts of the warp yarns that are to remain undyed are tightly entwined with a thick thread. The yarns are then dyed and set on the loom, whereby the undyed parts of the yarn form a light-coloured pattern on a dark ground. Other natural fibres such as silk, cotton and wool, absorb indigo blues more easily using a dye bath and the colour is more pronounced.

Indigofera longiracemosa is also used as a green manure. In Madagascar a decoction of the leaves is used as a diuretic. In India the root has been used in tribal medicine as an antidote for snake poisons.

Properties *Indigofera* plants contain the glucoside indican. After soaking the plants in water or pounding the leaves, enzymic hydrolysis transforms indican into indoxyl and glucose. Indoxyl is then oxidized and polymerized to indigotin (indigo-blue). Indigotin is insoluble in water, so to dye textiles it must be reduced to a soluble 'leuco' or colourless form (indigo-white) by a chemical or fermentation process under alkaline conditions. The cloth to be dyed is soaked in this solution. Subsequent re-oxidation of the indigo-white results in the precipitation of the blue indigo colour on the textile. Natural indigo also contains varying proportions of the chemically related dye compounds: indirubin (red), isoindirubin (red) and isoindigo (brown).

Botany Erect annual or short-lived perennial herb or subshrub up to 2 m tall; stem red-brown, glabrescent; branches slender, bearing few small hairs. Leaves alternate, imparipinnate with 5–13 pairs of leaflets; stipules subulate, c. 2 mm long; petiole c. 1.5 cm long; leaflets elliptical, up to 2.5 cm × 1.5 cm, sparsely hairy, distinctly blue-green. Inflorescence a many-flowered, almost sessile, usually long and lax raceme up to 10(–14) cm long, often exceeding the leaves. Flowers bisexual, papilionaceous, c.

4 mm long; pedicel c. 1 mm long, strongly reflexed after flowering; calyx tubular, up to 1 mm long, 5 lobes longer than the tube, brown hairy; corolla pink, densely brown-hairy outside; stamens 10, c. 3 mm long, upper one free, the other 9 united; ovary superior, 1-celled, style long. Fruit a straight cylindrical pod up to 2 cm × 2.5 mm, not constricted between the seeds, pointed, sparsely hairy, brown, 4–6-seeded. Seeds flattened rectangular, 2.5 mm × 1.5 mm, pitted.

Indigofera is a very large genus, comprising about 700 species pantropically, with more than 300 in tropical Africa.

Indigofera stenosepala Baker is another minor source of indigo for dyeing, indigenous to Madagascar, where it is widespread and common. An infusion is used to stimulate the appetite and to treat stomach ulcers and other digestive disorders.

Ecology *Indigofera longiracemosa* is found in lowland, usually coastal regions up to 100 m altitude, in areas with an annual rainfall of 1000–1500 mm. In Madagascar it is found in dune vegetation or grassland on sand, often around villages, up to 200 m altitude. In Indonesia it is grown at about 1650 m altitude and is attacked by pests at lower altitudes.

Management *Indigofera longiracemosa* is occasionally cultivated but no cultivation methods are known. Cultivation is probably similar to that of *Indigofera arrecta* Hochst. ex A.Rich. In Madagascar domestic extraction of indigo was done in several ways. Commonly, harvested plants are stacked in a big container (a barrel with a tapped hole at the bottom). Water is added to cover the plants and they are weighed down with a stone. The plants are left under water for about 12 hours, or as long as air bubbles come to the surface. Then the extraction water is drained off through the hole at the bottom into another container. It is mixed with a solution of slaked lime (in volume proportion 3:1) and well beaten to bring in oxygen and allow the formation of indigotin. Agitation and the addition of small amounts of lime water continue until blue indigo particles are formed. Now stirring continues but without addition of lime water. Then the liquid is left undisturbed for some time to allow the indigo to precipitate on the bottom. After pouring off the waste liquid, the indigo paste is collected into a mould with small holes on all sides that allow the evacuation of remaining water. When the paste is firm enough, it is taken out of the mould and the loaf is left to dry in the shade (sun would taint it pale blue). When dry the loaves are cut and packed, being ready for use or trade. Out of 10 kg fresh leaves, this domestic scale method produces 26 g of indigo with an average indigotin content of about 31%.

In an alternative method for preparing the dye bath or vat in Madagascar, fresh *Indigofera* leaves are pounded and the paste is left to ferment by specific bacteria. A concentrated infusion of fresh leaves is added repeatedly to keep the paste moist. When the indigotin has fully developed in this compost, the paste is used to set a vat with boiling water and ashes from burnt banana-plant stumps. The ash-lye serves to maintain the alkaline pH necessary for the reduction of the indigotin to soluble indigo-white by a biological process. After a few days, when the reduction is complete, dyeing can take place by repeated alternate dipping and airing of the skins or textiles. Depending on the number of dippings, the shades of blue obtained vary from pale greyish blue to dark navy blue. Different proportions of fresh leaves and compost, and different stages of compost fermentation may produce various shades of greenish blues, while the proportion of indirubin, an isomer of indigotin produced in the process, may give pinkish-purplish shades.

Genetic resources and breeding *Indigofera longiracemosa* is not in danger of genetic erosion.

Prospects *Indigofera longiracemosa* will remain a minor but locally important source for indigo dyeing. If current programmes to revive the use of natural dyes in traditional textiles of Madagascar lead to commercial success, interest in natural indigo will also increase, as well as cultivation of *Indigofera* species.

Major references Decary, 1946; du Puy et al., 2002; Etheve, 2005; Nogué, 1900.

Other references Gillett, 1958; Gillett et al., 1971; Sosef & van der Maesen, 1997.

Authors P.C.M. Jansen

INDIGOFERA TINCTORIA L.

Protologue Sp. pl. 2: 751 (1753).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

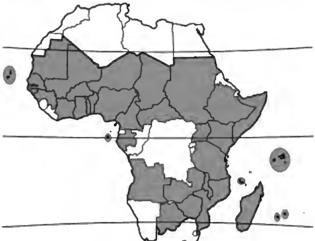
Chromosome number $2n = 16$

Synonyms *Indigofera sumatrana* Gaertn. (1791).

Vernacular names Indian indigo, common indigo (En). Indigotier tinctorial, indigotier des Indes (Fr). Anileira dos tintureiros, anileira da India (Po). Mnili, mnyuka (Sw).

Origin and geographic distribution The origin of *Indigofera tinctoria* is not known; it possibly originates from India. Its range has been greatly extended by its cultivation for indigo and subsequent naturalization. It occurs wild or naturalized in most countries of Africa, in Asia from Arabia to South-East Asia and in Australia. In Madagascar it seems to occur wild, while in most other Indian Ocean islands it probably has been introduced and sometimes naturalized. In tropical America it certainly has been introduced. Due to its historical exploitation and cultivation it is now distributed pantropically. The use of indigo extracted from *Indigofera* species has a long history. Indigo plants and the dyestuff were already mentioned in the oldest Sanskrit records. The blue dye used for textiles of Egyptian mummies may, in some cases, come from an *Indigofera* species but woad (*Isatis tinctoria* L.) is another indigo-blue producing plant known to ancient Egyptians. The most ancient archaeological textiles discovered in West Africa, the 'Tellem textiles', were found in funeral caves in the Bandiagara cliff in the Dogon area of Mali. Some of them date back to the 11th or 12th centuries and already include stripes, checks and tie-and-dye patterns done with indigo from *Indigofera* or *Philenoptera* species. An early description of the local extraction process of indigo from an *Indigofera* species in Guinea was left by the Portuguese explorer André Alvares de Almada in 1566.

Uses Leafy twigs of *Indigofera tinctoria* and some closely related *Indigofera* species are the main sources of the indigo dye used since very ancient times for dyeing textiles blue. The leaves and twigs do not contain indigo but colourless precursors that must be extracted and processed to produce the indigo dye. Because of its fascinating deep blue colour, its great colour fastness to light and the wide range of colours obtained by combining it with other natural dyes, indigo has been called 'the king of dyes'. No other dye plants have had such a prominent place in as many civilizations as *Indigofera* species. In western Africa indigo is by far the most important dye of plant origin. It plays an important role in traditional cultures of many people, whether only wearers of indigo-dyed textiles like the Tuareg in the Sahara and Sahel region (Niger, Mali), or renowned indigo dyers, among which the Soninke (Sarakole) and Wolof in Senegal, the Marka women of the Djenné region in Mali, the Dyula and Baule in Côte d'Ivoire, the Yoruba and Hausa in Nigeria and the Bamoum and Bamileke in Cameroon. This part of the world is a major centre of textile decoration techniques based on the concept of 'resist-dyeing' and linked with indigo dyeing: intricate patterns are made on the cloth that will resist being dyed. This is done by tying, sewing or plaiting parts of the cloth or by covering them with starch pastes or wax. The piece of cloth is then plunged into the indigo vat to dye the untreated parts. After the resist threads or pastes have been removed, white patterns on a blue ground appear. Light blue patterns on a blue-black ground are formed if a last indigo bath is given after undoing the resist. In Madagascar too, indigo dyeing is very important, for instance in raffia ikats, beautiful textiles in which the 'resist' patterns are formed by tying parts of the warp yarns with thick threads before dyeing them with indigo and putting them onto the weaving loom, which again creates white designs on a blue ground. However, the use of natural indigo is rapidly declining and nowadays, synthetic indigo is almost exclusively used, not only in industrialized processes but also at craft level.



Indigofera tinctoria – wild and planted

Indigofera tinctoria is useful as green manure, used e.g. in India in coffee plantations and preceding rice, maize, cotton and sugarcane. In traditional rainfed rice cropping systems in the Philippines *Indigofera tinctoria* is a popular green manure, increasing rice yield while reducing the need to supply expensive nitrogen fertilizer to about half. The residue remaining after indigo extraction is also applied as manure. Another reason to grow *Indigofera tinctoria* as green manure is because it is a good N catch crop, reducing the amount of fertilizer NO_3 leaching to the groundwater. As fodder

Indigofera tinctoria is hardly of value. In Kenya it is sometimes fed to camels and sheep, and goats occasionally eat it, but in India it is considered unpalatable to cattle.

In Cameroon twigs are used as a toothbrush. In traditional medicine leaf extracts (sometimes taken with honey or milk) are used to treat epilepsy, nervous disorders, asthma, bronchitis, fever, complaints of stomach, liver, kidney and spleen, as a rabies prophylactic, and as an ointment for skin diseases, wounds, sores, ulcers and haemorrhoids. A leaf extract is also used to treat burns and sores on cattle and horses. A tincture of the seed is used in India to kill lice. A root preparation is applied in Cameroon to relieve toothache, in Tanzania as a remedy against syphilis, gonorrhoea and kidney stone and in India a watery root paste is applied to worm-infested wounds. In India a root infusion is used as an antidote against snakebites and to treat insect and scorpion stings.

Production and international trade Already in antiquity indigo was traded from India to the Mediterranean region, but this became more important during the Middle Ages. Large-scale cultivation of *Indigofera* started in the 16th century in India and south-eastern Asia. Later, large plantations were established in Central America and the southern United States. The large-scale export of indigo from Asia to Europe started in about 1600 and had to compete with dye from woad which was cultivated mainly in France, Italy, Germany and Great Britain. By the end of the 17th century, indigo had almost completely replaced woad. Synthetic indigo, which came into commercial production in 1897, proved catastrophic to the production of natural indigo, and by 1914 only 4% of the total world production was of plant origin. Then followed a period in which synthetic indigo lost some of its importance due to competition from new synthetic dyes, but the ever growing popularity of blue jeans enormously contributed to a revival of interest in indigo. At present, the crop is still cultivated for dye production on a small scale in India and in some parts of Africa, southern Arabia (Yemen), Central America and Indonesia. The most important present-day centre of indigo production from *Indigofera* is probably the northern part of Karnataka state in India. In India, annual production of *Indigofera* dye gradually decreased from 3000 t from 600,000 ha in 1890, to 50 t from 4000 ha in the 1950s, to an annual export fluctuating between 2 t and 20 t in the 1990s.

Properties *Indigofera* plants contain the glucoside indican. After soaking the plants in water, enzymic hydrolysis transforms indican into indoxyl and glucose. Indigotin (often also called indigo or indigo-blue) formation results from the grouping of two molecules of indoxyl in the presence of oxygen. Indigotin is insoluble in water, so to dye textiles it must be reduced to a soluble form (colourless 'leuco' indigo or indigo-white) by a fermentation process under alkaline conditions or by a chemical reducing agent such as sodium dithionite. Subsequent oxidation by airing of the textile after its removal from the dye bath, results in the regeneration of indigotin and fixation of the blue colour onto the textile. Natural indigo can contain varying proportions of a chemically related red dye called indirubin and of the minor isomeric compounds isoindirubin (red) and isoindigo (brown).

The leaves of *Indigofera tinctoria* contain per 100 g dry matter approximately: N 5.1 g, P 0.35 g, K 1.4 g, Ca 3.9 g. The ash (4.4 g) contains up to 9.5% soluble potassium salts. The indigo refuse after dye extraction contains approximately: N 1.8 g, P 0.2 g, K 0.25 g.

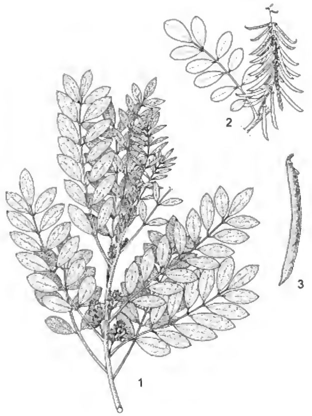
The traditional use of *Indigofera tinctoria* against liver problems is supported by research findings. Indigtone, a bioactive fraction obtained by fractionation of a petroleum ether extract of the aerial parts of *Indigofera tinctoria*, showed significant dose-related hepatoprotective activity against carbon tetrachloride induced liver injury in rats and mice. Alcoholic extracts had a very positive effect on the liver antioxidant defence system during D-galactosamine/endotoxin-induced acute hepatitis in rodents. Methanolic extracts of whole plants showed anti-HIV activity in cell cultures.

Indigofera tinctoria has insecticidal properties and contains 6 rotenoids: deguelin, dehydrodeguelin, rotenol, rotenone, tephrosin and sumatrol. Rotenoid concentrations reported are 0.5% in roots, 0.3% in stems, 0.6% in leaves, 0.3% in fruits and 0.4% in seeds. The contents decrease with increasing age of the plant. Sumatrol and tephrosin were not produced in callus cultures of *Indigofera tinctoria*. In tests the insecticidal property varied. The toxicity of the rotenoids was greater to larvae of the mosquito *Anopheles stephensi* than to adults of the pulse beetle *Callosobruchus chinensis*. Extracts obtained from callus cultures were more effective than those obtained from plant parts. The rotenoids had a LD_{50} value of about 117 ppm against the crustacean *Mesocyclops leuckarti*, the carrier of

Guinea worm larvae (*Dracunculus medinensis*) which is present in infected drinking water and causes a dangerous parasitic worm infection in humans. Root extracts of *Indigofera tinctoria* have a strong nematicidal property against *Radopholus similis* in bananas.

Adulterations and substitutes Several other, often unrelated, plant species are sources of indigo dyes. Examples include woad from Europe, *Polygonum tinctorium* Aiton from China, Korea and Japan, Assam indigo (*Strobilanthes cusia* (Nees) Kuntze) from Indo-China and Thailand and *Marsdenia tinctoria* R.Br. from tropical Asia. In West Africa, gara (*Philenoptera cyanescens* (Schumach. & Thonn.) Roberty) and Gambian indigo (*Philenoptera laxiflora* (Guill. & Perry) Roberty) are important sources of indigo. They also contain indican and are often combined with indigo from *Indigofera* species in traditional indigo dyeing processes. Other natural sources of indigo are a mutant of the fungus *Schizophyllum commune* and the purple snail *Hexaplex trunculus*, which mostly contains precursors of indigo and only minor proportions of the bromine derivatives of indigo of which the famous Tyrian purple dye of antiquity was composed. The most important substitute of natural indigo, however, is the synthetic industrial product.

Description Annual to perennial herb or subshrub up to 2 m tall; stem erect, copiously branched, covered with appressed, whitish, 2-branched hairs. Leaves arranged spirally, imparipinnate; stipules narrowly triangular, 1.5–3 mm long; petiole up to 2 cm long, rachis up to 7 cm long; stipels narrowly triangular, up to 0.5 mm long; petiolules c. 1 mm long; leaflets (3–)7–17(–21), elliptical to obovate, up to 23 mm × 12 mm, usually glabrous above, thinly hairy below. Inflorescence a sessile, many-flowered axillary raceme up to 6 cm long but usually much shorter; bracts narrowly triangular, c. 1 mm long, more or less persistent. Flowers bisexual, papilionaceous; pedicel 1–1.5 mm long; calyx c. 1 mm long, the tube about as long as the 5 triangular lobes, white appressed hairy; corolla c. 4 mm long, standard ovate, c. 4 mm × 3.5 mm, whitish with reddish rays, wings with very short claws, pinkish, keel laterally spurred, pink to red; stamens 10, 4–5 mm long, upper one free, the other 9 united into a tube; ovary superior, 1-celled, with long style. Fruit a linear pod 20–35 mm long and c. 2 mm wide and thick, straight or slightly curved, rounded in cross-section, brown when ripe, 7–12-seeded with slight constrictions between the seeds. Seeds shortly oblong, c. 2 mm × 1.5 mm, rhombic in cross-section. Seedling with epigeal germination; cotyledons thick, short-lasting.



Indigofera tinctoria – 1, flowering branch; 2, part of fruiting branch; 3, fruit.
Redrawn and adapted by Achmad Satiri Nurhaman

Other botanical information *Indigofera* is a very large genus comprising approximately 700 species and is distributed throughout the tropics and subtropics of Africa, Asia and the Americas. Africa and the southern Himalayas are richest in species. Over 300 species have been recorded for tropical Africa.

For indigo production several *Indigofera* species are used but there are 3 closely related major ones: *Indigofera tinctoria*, *Indigofera arrecta* Hochst. ex A.Rich., which originates from tropical Africa but is now distributed pantropically, and *Indigofera suffruticosa* Mill., originating from tropical America and now locally cultivated elsewhere in the tropics, including Africa and Madagascar but not in tropical East Africa. The origin and identity of *Indigofera* plants cultivated for dye production is often obscure as a result of introduction, selection and the close affinity of species. *Indigofera arrecta* is sometimes difficult to separate from *Indigofera tinctoria*. The latter usually differs in its larger and less numerous leaflets and longer fruits containing more seeds. In East Africa, but not in West Africa, *Indigofera arrecta* generally occurs at higher altitudes (1000–2000 m) than *Indigofera tinctoria* (below 1000 m). *Indigofera suffruticosa* differs from *Indigofera tinctoria* by its rather straight, short, 10–15 mm long, red-brown pods and shorter (c. 3 mm long) stamens. Intermediate specimens between these 3 species have been found, possibly of hybrid origin. Based on the form of the fruits, 2 varieties are distinguished in *Indigofera tinctoria*: var. *tinctoria* has straight or slightly curved pods (not more than 50°), var. *arcuata* J.B.Gillett has pods curved more than 50°, often semi-circular and sometimes forming a ring.

Growth and development Seeds germinate in about 4–5 days. Plants may start to flower 3–4 months after sowing. Like many other leguminous plants, *Indigofera tinctoria* forms root nodules with nitrogen-fixing capacity with e.g. *Rhizobium indigoferae*. The total lifespan for dye crops is 2–3 years when grown as a ratoon crop.

Ecology *Indigofera tinctoria* occurs in seasonally flooded grassy fields with scattered trees, and also in roadsides, bush margins, brushwood and secondary forest, and on riverbanks, cultivated grounds and sandy coasts. It occurs at 0–1000(–1250) m altitude, in regions with an annual rainfall of 500–1500(–4100) mm and average annual temperature of 23°C. Too much continuous rain, waterlogging and flooding kill plants; excessive heat and hot winds cause withering.

Propagation and planting Propagation is by seed, of which 20–30 kg/ha is needed. The seeds commonly have a hard seed coat (sometimes more than 85%) and soaking overnight in water or scarification with sulphuric acid can improve germination to over 90%. Fields are prepared by hoeing or by one or two ploughings after showers followed by light harrowing before and after broadcast sowing. Sowing in a nursery and transplanting into the field may also be practised.

Management The crop normally requires little attention after sowing. Weeding is done when needed. Although *Indigofera tinctoria* is nitrogen fixing by its root nodules, additional N fertilization is not uncommon.

Diseases and pests No reports on diseases or pests are available for African countries. In Java *Indigofera tinctoria* is little susceptible to diseases or pests; in humid conditions lignified plants may be attacked by *Corticium salmonicolor*. In the Philippines pests include chrysomelid beetles and *Cletus* spp. in the seedling stage and aphids in the vegetative stage. In southern India extensive wilting and drying of *Indigofera tinctoria* occurs due to infestation by the psyllid *Arytaina punctipennis*.

Harvesting Branches are harvested by cutting 10–20 cm above ground level when the plants are 4–5 months old and have formed a closed stand, usually at the flowering stage. The crop should be harvested promptly because heavy rains or flooding can destroy it in a few hours. In India harvested branches are tied into bundles of about 130 kg and transported to the dye factory. Up to 3 harvests are possible per year when it is grown as a ratoon crop.

Yield In India the yield of green plant material per harvest is 10–13 t/ha. The dye yield is not known.

Handling after harvest In small-scale cultivation in Africa, harvested branches are often pounded to a soft pulp and made into balls, which are sold on the market after drying. This is the method described by André Alvares de Almada in 1566 and in all early reports. In large-scale cultivation the branches are put in a water containing tank or pit immediately after harvesting. After some hours of fermentation, during which enzymic hydrolysis leads to the formation of indoxyl, the liquid is transferred to another pit or tank and stirred continuously for several hours to stimulate oxidation of the indoxyl to indigotin. Afterwards, the solution is left to rest and the insoluble indigotin settles down to the bottom as a bluish sludge. The water is drained off, and after the indigotin has been washed to get rid of impurities, it is pressed, dried and usually cut into cubes which can be packed and sold.

To dye textiles, indigotin must be reduced to a soluble form under alkaline conditions. In traditional processes (indigo vats), the reduction of indigotin into soluble indigo-white is achieved through a bacterial fermentation. The reducing bacteria are obtained in the bath by adding vegetable matter such as the crushed indigo balls, or, when indigo powder is used, crushed balls of *Philenoptera* leaves, or, according to some recipes, molasses, coconut-milk, banana or guava leaves. An alkaline pH of around 8.2 is adequate and is maintained by adding a potash lye prepared from the ashes of different calcinated plants specially selected for this purpose in each region (among the Marka women of Mali the most appreciated species are *Adansonia digitata* L. (baobab), *Anogeissus leiocarpa* (DC.) Guill. & Perr., *Balanites aegyptiaca* (L.) Delile, *Bauhinia reticulata* DC. and *Faidherbia albida* (Delile) A.Chev.). Less often, the bath is made alkaline by adding freshly slaked lime. In the industrial process, an alkaline solution of sodium dithionite is used for reducing indigo to indigo-white. This polluting chemical process has now been adopted by most craft dyers. Often a gum (e.g. from *Acacia senegal* (L.) Willd. or *Anogeissus leiocarpa* (DC.) Guill. & Perr.) is added to make the coloured textile more durable and wind-proof. After the textile has been dipped into the solution of indigo-white, it turns blue when exposed to the air. Several dips are needed to impart a dark blue colour to the textile and especially to cotton fabrics, each dip followed by exposure to the air for some time. In Africa very often dyeing is followed by calendering, a finishing process that consists of beating indigo powder onto the surface of the cloth using heavy mallets to give the textile an iridescent, metallic shine, like on the Tuaregs' veils. This finish has both aesthetic and medicinal purposes: since the indigo powder is not fixed durably onto the cloth it discharges onto the skin of the people who wear such cloth and acts as a disinfectant and cicatrising drug. Textiles dyed with indigo are very colour-fast to light and washing, less so to rubbing.

Genetic resources Several germplasm collections of *Indigofera* exist, the largest being maintained at CSIRO, St. Lucia, Queensland, Australia (365 accessions) and CIAT, Cali, Colombia (250 accessions). In Africa, collections are present in Ethiopia (ILRI, Addis Ababa, 60 accessions), Kenya (e.g. National Genebank of Kenya Crop Plant Genetic Resources, Kikuyu, (40 accessions) and in South Africa (Pretoria).

Prospects In spite of its cultural importance, the use of indigo of vegetable origin has almost disappeared, being replaced by synthetic indigo. In West Africa colourful printed textiles, which have a long history in local fashions, are now the most important type of textiles worn by the majority of people and they are mainly imported from Asia or Europe. In recent years, with worldwide increasing concern for sustainability and the demand from consumers for natural products, there has been a revival of interest in natural indigo. Much research still has to be done to optimise indigo production from the most promising plants. *Indigofera tinctoria* is an interesting species in Africa because in addition to its potential as a dye producer, it can be useful as a green manure in agriculture and as a medicine in traditional healing. Its medicinal properties also deserve more research.

Major references Balfour-Paul, 1998; Burkill, 1995; Cardon, 2003; Duke, 1981; Gillett et al., 1971; Green, 1995; Lemmens & Wessel-Riemens, 1991; Oei (Editor), 1985; Schrire, 1998.

Other references Boser-Sarivaxévanis, 1969; de Melo, 1947; du Puy et al., 2002; Garrity et al., 1994; Gillett, 1958; Hepper, 1958; Kamal & Mangla, 1987; Kamal & Mangla, 1993; Kavimani et al., 2000; Leite et al., 2004; Malarvannan & Devaki, 2003; Miège, 1992; Monteil, 1971; Picton & Mack, 1979; Singh et al., 2001; Sreeja & Charles, 1998; Sreepriya, Devaki & Nayeem, 2001; Sudibyo Supardi & Hurip Pratomo, 2003; Sunarno, 1997; Sy, Grouzis & Danthu, 2001.

Sources of illustration Gillett et al., 1971; Mansfeld, 1986.

Authors R. Takawira-Nyenya & D. Cardon

LABOURDONNAISIA MADAGASCARIENSIS
Pierre ex Baill.

Protologue Bull. Soc. Linn. Paris 2: 917 (1898).

Family Sapotaceae

Vernacular names Nato, nantou, bois de natte (Fr).

Origin and geographic distribution *Labourdonnaisia madagascariensis* is endemic to eastern Madagascar.

Uses The bark of *Labourdonnaisia madagascariensis* is used for dyeing silk and cotton tissues red. Occasionally, the bark is also used for tanning hides. Bark decoctions of all *Labourdonnaisia* species are astringent and used to treat haemorrhages and menstrual problems.

Properties The bark of *Labourdonnaisia madagascariensis* contains tannin. Additional compounds such as phenols, leucoanthocyanins, anthraquinones, terpenes, alkaloids and saponins have been detected in the bark and leaves of other *Labourdonnaisia* species, and it is likely that similar compounds also occur in *Labourdonnaisia madagascariensis*.

Botany Small tree up to 10 m tall, with branches growing sympodially. Leaves arranged spirally, but clustered at the ends of branches, simple; petiole c. 2 cm long; blade oblong-oblanceolate, up to 12 cm × 4 cm, base cuneate, apex emarginate, margins strongly rolled back, leathery, both surfaces grey-waxy, midvein prominent, lateral veins numerous.

Inflorescence an axillary fascicle at the end of branches. Flowers bisexual, regular; pedicel up to 18 mm long; calyx with 6 hairy sepals in 2 whorls of 3, persistent; corolla with a short tube 1.5 mm long and 10–11 lobes up to 4.5 mm long, lobes sometimes split at apex and margins sometimes with small teeth; stamens 10–11, inserted at the top of the corolla tube, filaments 2.5 mm long, anthers up to 2 mm long, staminodes 2–6, very short; ovary superior, hairy, 6–10-celled, style narrowly conical. Fruit unknown, but probably a small fleshy 1-seeded berry (as in other *Labourdonnaisia* species).

Labourdonnaisia is a little known genus, comprising about 5–6 species, 3 of them in the Mascarenes and 2 or 3 in Madagascar. In non-taxonomic literature *Labourdonnaisia madagascariensis* has also been named *Imbricaria madagascariensis*.

Ecology *Labourdonnaisia madagascariensis* is found in humid evergreen coastal forest on sandy soils.

Management The harvested bark is dried and pulverized. The powder is put in boiling water, together with the fibres or textiles to be dyed. After 2 days of boiling, the red dyed fibres or textiles are taken out and dried in the sun. In another method part of the bark is broken into small pieces, which are tied together, and another part is pulverized. The pieces and the powder are put in a container with water. The container is heated until boiling in the morning and in the evening and this is repeated for up to 8 days until the dye bath has obtained the desired red colour. Then the bark pieces are taken out and replaced by the fibre or textiles. This mixture is heated again and when the fibre or textile has obtained the right colour it is taken out and dried. If necessary the same operation is repeated a second time.

Genetic resources and breeding *Labourdonnaisia madagascariensis* is probably uncommon because only one herbarium collection is known. It deserves protection and germplasm conservation.

Prospects *Labourdonnaisia madagascariensis* is very poorly known. Only further research can enlighten its value as a dye and tannin source in Madagascar, and indicate whether stands of some importance still exist.

Major references Aubréville, 1974; Decary, 1946; Schatz, 2001.

Other references Aubréville, 1971; Aubréville, 1972; Friedmann, 1981; Gurib-Fakim & Brendler, 2003.

Authors P.C.M. Jansen

LAGUNCULARIA RACEMOSA (L.) C.F.Gaertn.

Protologue Suppl. carp. 2(2): 209, pl. 217 (1807).

Family Combretaceae

Vernacular names White mangrove (En). Palétuvier blanc, palétuvier gris, mangle blanc, mangle gris (Fr). Mangue branco (Po).

Origin and geographic distribution *Laguncularia racemosa* is found in mangrove vegetations along the Atlantic Ocean in Africa and along the coasts of the Atlantic as well as Pacific Ocean in Central and South America. In Africa it is found from Senegal to Angola.

Uses The bark and leaves of *Laguncularia racemosa* produce a tannin and a brown dye of good quality, but not in quantities that are economically interesting. The bark is used to treat fishing nets for longer preservation. In experiments with bark from Caribbean samples, the bark was found to contain 12–24% tannin and the leather prepared from it was of excellent quality. Though the leaves contain 10–20% tannin they are browsed by camels. The flowers are said to be useful in honey production and in Guinea Bissau the fruits are eaten. The wood is heavy, hard, strong and close-grained; it is mainly used as firewood, rarely for construction and wooden utensils. A bark infusion is used as an astringent, tonic and folk remedy for dysentery, aphthae, fever and scurvy. It is also attributed some antitumour activity.

Properties Neither the tannin, nor the dye appear to have been investigated and characterized. Untreated poles of *Laguncularia racemosa* in contact with the ground served for only 2–3 years. If treated with preservatives the service time is 10 years or more. Gum exudate from the bark contains sugars (galactose, arabinose and rhamnose), galacturonic acid, glucuronic acid and its 4-O-methyl ether. The gum is similar to that of many *Combretum* species, giving acidic solutions, with low nitrogen content and high rhamnose content after acidic hydrolysis. The gum has been used in combination with agar as a cheap substrate for in vitro fungi cultures.

Botany Shrub up to 3 m tall, or occasionally tree up to 25 m tall with bole up to 70 cm in diameter, irregularly branched, sometimes with pneumatophores, with rough, fissured, grey bark exuding a gum when wounded. Leaves decussately opposite, simple and entire, somewhat fleshy, glabrous; stipules absent; petiole 1–2 cm long, slightly grooved above, bearing 2 circular glands near the apex; blade elliptical to obovate, 5–10 cm × 3–6 cm, base truncate, apex rounded to slightly emarginate, usually with small glandular dots below. Inflorescence a spike aggregated into a loose terminal panicle. Flowers unisexual or bisexual, regular, 5-merous, 4–5 mm in diameter; receptacle cup-shaped with small acute calyx lobes, hairy; petals free, circular, c. 1 mm in diameter, whitish green, early falling, hairy outside; stamens 10; disk conspicuous; ovary inferior, 1-celled, style simple, 1–2 mm long. Fruit a ribbed, 1-seeded nut c. 2 cm long, hairy, with the persistent remains of the calyx at apex. Seed with spongy seed coat. Seedling with epigeal germination.

Laguncularia racemosa is the only species of the genus and can be recognized by its opposite, bluntly obovate, somewhat fleshy leaves with a pair of conspicuous glands on the petiole just below the blade. It is much branched, but many branches are aborted resulting in numerous dead or dying branches. It is predominantly dioecious, but bisexual individuals are also found. Flowering starts when plants are about 2 years old and occurs all year round; pollination is by insects. Fruiting is abundant and usually a carpet of seedlings is produced but most seedlings die in the first year. The fruits are dispersed by water. Most glands on the leaf blade function as salt glands and the salt solution may crystallize so rapidly that crystals are extruded in chains from the mouth of the gland.

Ecology *Laguncularia racemosa* is typically restricted to the landward fringe of mangrove vegetations, and it is also a pioneer on disturbed sites where it can form pure stands. For good growth it needs full light.

Management *Laguncularia racemosa* can be propagated by seed and rooted cuttings. Vegetative propagation is important in reforestation programmes in mangrove-suitable areas. The most important factor for survival of cuttings is rooting of the shoots prior to cutting from the parent trees. Under natural conditions rooting occurs often after flooding. Rooted cuttings can even be planted in salt water and they start flowering within a year.

Genetic resources and breeding *Laguncularia racemosa* is widespread and does not seem to be in danger of genetic erosion. However, in many areas mangrove vegetations, of which *Laguncularia racemosa* is an element, are under pressure caused by human activities.

Prospects *Laguncularia racemosa* will remain of minor importance as source of tannin. Its use as a fuel plant is possibly of more economic importance.

Major references Burkill, 1985; Irvine, 1961; Jiménez, 1985; Tomlinson, 1986.

Other references Académie de la Martinique, undated; De Pinto et al., 1993; Elster & Perdomo, 1999; Jongkind, 1999; Liben, 1983.

Authors P.C.M. Jansen

LANNEA BARTERI (Oliv.) Engl.

Protologue Nat. Pflanzenfam., II–IV Nachtr. 1: 213 (1897).

Family Anacardiaceae

Synonyms *Lannea kerstingii* Engl. & K.Krause (1911).

Origin and geographic distribution *Lannea barteri* occurs from Guinea east to Ethiopia and Uganda and south to DR Congo and Burundi.

Uses The bark of *Lannea barteri* yields a dye which is used in Côte d'Ivoire, Mali, Burkina Faso and Ghana. Its red-orange-brown colour is associated with blood and war as well as mourning. In Ghana the dye, known in Akan as 'kuntunkuni' or 'kobewu', serves to give the symbolic dark red to red-brown colour of 'adinkra' clothes worn at the funerals of chiefs and afterwards by their mourning relatives. The name 'adinkra' may be derived from 'nkradie' or 'dinkra' which means 'good-bye'. It is also the name of the technique by which these red mourning clothes and other types of fabrics are decorated with hand-stamped black designs.

The resinous fruit pulp is eaten occasionally, the fibrous bark is used to make ropes and the flowers attract bees and may be useful for honey production. The wood is used in Uganda for firewood and charcoal, and to make small utensils (e.g. mortars), and the plant is sometimes cultivated as a live fence as it coppices easily. The bark is used externally to treat ulcers, sores and leprosy. A decoction is drunk against gastric pains, diarrhoea, oedema, paralysis, epilepsy and madness. In Nigeria (Igbo) and the Central African Republic a bark decoction is drunk as a stomachic and is part of a vermifuge medicine. The macerated root is used in a poultice for the treatment of wounds. In Burkina Faso a root decoction is taken to cure hernia and a leaf decoction to cure haemorrhoids.

Properties The bark of *Lannea barteri* has not been investigated concerning dye and tannin components, but the popular use of several *Lannea* species in many African countries obviously deserves systematic research. The bark also contains a gummy secretion which becomes white and friable in contact with air. The wood is soft, dirty white, coarse-grained and without much value.

Botany Dioecious tree up to 18 m tall; bole usually straight, up to 40 cm in diameter, bark thick, spirally grooved, rather smooth, grey. Leaves alternate, pinnately compound with (1–)2–6 pairs of opposite leaflets and a terminal one; rachis 10–25 cm long; leaflets shortly stalked, but terminal leaflet with long stalk, ovate to elliptical, 7–17 cm × 4–11 cm, obtuse to slightly cordate at base, apex mucronate, margin entire, yellow-brown velvety pubescent, with 11–15 pairs of secondary veins. Inflorescence a terminal spike-like raceme up to 25 cm long, arranged in apical clusters and produced before leaves. Flowers unisexual, regular, 4-merous; pedicel up to 3 mm long; calyx cup-shaped with lobes c. 1 mm long, ciliate; petals oblong, 2–3.5 mm × 1.5 mm, yellowish, with darker veins; male flowers with 8 stamens; female flowers with superior, 4-celled ovary, styles 4, stigmas headlike, often with 8 staminodes. Fruit a compressed cylindrical drupe 10–13 mm × 7–8 mm, glabrous, purplish-red.

Lannea comprises about 40 species, most of them restricted to Africa. In Guinea, Côte d'Ivoire and Benin *Lannea egregia* Engl. & K.Krause has the same vernacular names as *Lannea barteri* and is certainly used similarly, including for dyeing purposes. *Lannea egregia* is found from Guinea to Nigeria in savanna vegetation. It is a tree up to 15 m tall, with spirally grooved grey bark, and pinnately compound leaves with 3–5 pairs of leaflets plus a terminal one. For other *Lannea* species of which the bark is also used as a source of red-brown dye in Africa, see *Lannea microcarpa* Engl. & K.Krause.

Lannea barteri trees flower when they are leafless, in Ghana between December and April.

Ecology *Lannea barteri* occurs in wooded savanna and forest edges, and near rivers, usually at 500–1600 m altitude.

Management Seed or cuttings can be used for propagation. The seeds can be collected from fallen fruits, dried and sown within 2 months. Cuttings strike easily, even when taken from large branches.

For dyeing cotton cloth, the bark of *Lannea barteri* is pounded or cut up into small pieces and boiled in water for a long time. The cooled decoction is filtered and the fabric to be dyed is kept in the dye bath for at least 24 hours. Red, red-brown or orange-red colours are obtained without mordanting. In Ghana, to decorate 'adinkra' cloth, several pieces of dyed cloth are sewn together with ornate embroidery. Then stamps carved from calabashes are dipped into the thick black ink obtained by the prolonged decoction of the bark of the 'badie' tree (*Bridelia ferruginea* Benth.) with lumps of iron slag. This ink is called 'adinkra aduru' ('adinkra medicine'). Different stamps carved with many different designs are applied onto the cloth, juxtaposed in rectangular blocks across the whole surface of the piece.

Genetic resources and breeding *Lannea barteri* is rather widespread and although it is nowhere very common, it does not seem to be in danger of genetic erosion.

Prospects *Lannea barteri* is an important source of red-brown dye used in traditional dyeing in Africa. With a growing interest in and demand for African textile art, it is expected that the economic importance of *Lannea barteri* will increase. Its dye and tannin contents, medicinal properties and possibilities for cultivation need further research.

Major references Arbonnier, 2004; Burkill, 1985; Cardon, 2003; Katende, Birnie & Tengnäs, 1995; Polakoff, 1980; van der Veken, 1960.

Other references Aké Assi et al., 1985; Geerling, 1982; Gilbert, 1989; Irvine, 1961; Keay, 1958; Kerharo & Bouquet, 1950; Kokwaro & Gillett, 1980; Kokwaro, 1986; Neuwinger, 2000; Taïta, 2000.

Authors P.C.M. Jansen

LANNEA MICROCARPA Engl. & K.Krause

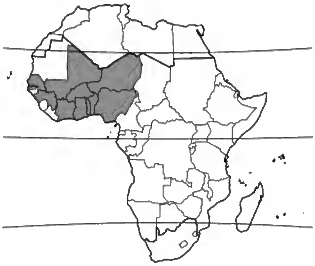
Protologue Bot. Jahrb. Syst. 46: 324 (1911).

Family Anacardiaceae

Vernacular names African grape (En). Vrai raisinier (Fr).

Origin and geographic distribution *Lannea microcarpa* is indigenous from Senegal to Cameroon.

Uses In West Africa the bark of *Lannea microcarpa* is employed to dye cotton textiles a red-brown colour. It is one of the main plants used in the production of the cloths called 'basilan fini' (medicine applied on cloth), widely associated with the notion of healing, since the decoction of the plant is both medicinal and dyes the colour of blood. Garments made with plain



Lannea microcarpa – wild

ochre-red cloth or with black designs on an ochre-red ground obtained with this dye are mostly worn by men, originally in blood-shedding circumstances such as hunting and war. The red dye has protective symbolic power, hides bloodstains and is believed to heal the wounds. It is also used by both sexes for ritual clothes worn at crucial stages of life such as circumcision and excision, delivery and death. In Mali Bambara women use *Lannea microcarpa* to decorate textiles called 'surusuru' and 'basiya'. These textiles belong to the bogolan group. Women's wrappers dyed with *Lannea* bark are worn at the occasions of excision, delivery, menopause and lastly as a shroud. In Ghana among the Akan and the Ashanti people, the dye from the bark is traditionally used for mourning clothes although red synthetic dyestuffs may now be used instead.

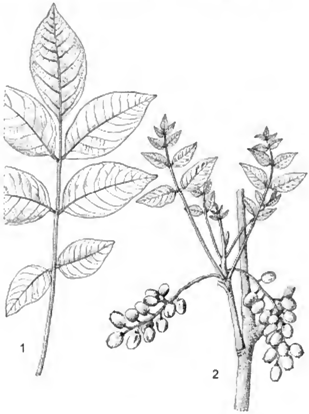
The young leaves are eaten as a vegetable and cattle browse leaves as a forage. The fruits are eaten raw or dried and a fermented drink is prepared from the pulp. The wood is white, light, easy to work but deteriorates quickly; it is used in Senegal to make hoe handles and throughout West Africa as fuel and to make charcoal. Ropes are made from the very fibrous bark. The bark yields an edible gum which is soluble in water. In Benin dried pulverized aerial parts are rubbed into scarifications against pain between the ribs and are taken internally against colic. A leaf decoction is drunk to treat swellings; it is also added to a bath. In Ghana leaves are used as a dressing for wounds. In Senegal wood ash is applied to maturate abscesses. In Nigeria leaves, bark, roots and fruits are applied to treat mouth blisters, rheumatism, sore throat, dysentery, as a cathartic and as a dressing on boils.

Properties Tannins (deriving from gallic acid) are present in the bark and react with the iron-rich mud used in the bogolan process to give the characteristic black ground or designs of 'basiya' and 'surusuru' textiles.

The fruits contain anthocyanins, about 1300 mg per 100 g dry pulp. The main anthocyanin glycosides present are two different galactopyranosides of cyanidin: cyanidin 3-O-(2-O-β-D-xylopyranosyl)-β-D-galactopyranoside (0.15%) and cyanidin 3-O-β-D-galactopyranoside (0.45%).

The antidiarrhoeic effect of the bark has been confirmed by tests.

Description Dioecious tree up to 15 m tall; bole up to 70 cm in diameter, rather short; bark grey, slightly sweet-scented, smooth or with small scales when older, often with a spiral twist, very fibrous, slash reddish with fine white markings. Leaves alternate, imparipinnate, up to 25 cm long with 2–3(–5) pairs of leaflets; stipules absent; leaflets ovate, 5–13 cm × 2.5–6 cm, base attenuate to rounded, apex more or less pointed, margin entire but often slightly undulate, upper surface with glandular resin dots, particularly in young leaves, pin-



Lannea microcarpa – 1, leaf; 2, part of branch with young leaves and fruits.
Redrawn and adapted by Iskak Syamsudin

nately veined. Inflorescence a terminal raceme up to 15 cm long (male ones longest), bearing glandular dots. Flowers unisexual, regular, 4-merous, c. 4 mm in diameter, green-yellow; male ones with 8 stamens; female ones with superior 4-celled ovary bearing 4 styles. Fruit an ellipsoid, glabrous drupe, c. 1.5 cm long, on top bearing up to 4 small teeth, purplish-black when mature, 1-seeded.

Other botanical information *Lannea* comprises about 40 species, most of them restricted to Africa, and the bark of many of them is or has been used as a source of a red-brown dye. Although most species can easily be distinguished botanically, in several areas different species bear similar vernacular names. Therefore, the exact identity of the species used in a particular dyeing process is not always certain, except from field observations complemented by botanical identification of the collected dye material. It is also possible that bark mixtures are used sometimes.

Lannea acida A.Rich. is used for dyeing in the same way as *Lannea microcarpa* in Mali where it bears the same vernacular name 'npeku' in the Bamanan language. In Côte d'Ivoire a red dye is made from a bark decoction with the addition of wood ash. It turns yellow if acids are added to the bath. In this process a mordant has to be used. However, *Lannea acida* is more important medicinally.

The bark of *Lannea schweinfurthii* (Engl.) Engl. is used by the Tsonga people of Gazankulu of north-eastern South Africa to dye basket material a purplish-brown colour, but this species is more important for its edible fruits.

The bark of *Lannea welwitschii* (Hiern) Engl. is used in the same way as that of *Lannea acida* in Côte d'Ivoire and Ghana to dye wrappers reddish brown.

Growth and development Leaves fall off at the beginning of the dry season; flowering is at the end of the dry season, before the appearance of the new leaves.

Ecology *Lannea microcarpa* occurs in savanna vegetation. It prefers deep friable soil and is often found on cultivated land, where it is not cut down but preserved for its edible fruits. It also occurs on rocky soil in Sahel savanna.

Propagation and planting *Lannea* species are not cultivated for dyeing purposes. They can be propagated by seed. Ambient temperatures of 25–30°C much reduce the longevity of the seeds. At a moisture content of about 6% the seeds keep their viability longer when kept at lower temperatures, and long storage is possible in a freezer at −18°C.

Handling after harvest The bark is pounded and boiled for 2–3 hours in water. Towards the end of this period a small ladleful of wood ash is added as mordant, resulting in a darker coloured liquid that is kept boiling strongly for about half an hour. After it has cooled down, the decoction is filtered and is then ready for use as a dye bath. To obtain a faster colour, bogolan dyers associate this dye with a decoction of the bark of *Anogeissus leiocarpa* (DC.) Guill. & Perr. The cotton cloth is plunged once into the *Lannea* dye-bath, then 3 times in the *Anogeissus* bath and finally once again in the *Lannea* bath. Between each dyeing, the cloth is dried in the sun. Subsequently the cloth is dyed using iron-rich mud of the bogolan technique. The dye is not very fast, except in the black parts of the design.

Genetic resources *Lannea microcarpa* is widespread and is not in danger of genetic erosion. In the northern parts of Burkina Faso it is considered vulnerable.

Prospects The use of *Lannea* bark for red dyeing is still important and widespread in West Africa. As the dye is becoming more and more popular in the modern forms of the bogolan textile production, cultivation of the main local species, *Lannea microcarpa* and *Lannea acida*, is to be recommended, especially since they also produce edible young leaves and fruits, and are used medicinally, particularly to cure skin affections.

Major references Arbonnier, 2004; Aubréville, 1950; Burkill, 1985; Burkill, 2000; Cardon, 2003; Duponchel, 2004; Irvine, 1961; Kerharo & Adam, 1974; Miège, 1992.

Other references Adjanohoun et al., 1989; Bensaï, 1994a; Bensaï, 1994b; Buckingham et al., 1994–1995; Coquet, 2001; Diallo et al., 2001; Duponchel, 1997; Galvez et al., 1990; Keay, 1958; Kerharo & Bouquet, 1950; Kokwaro, 1986; Liengme, 1981; Muteba Luntumbue, 1998; Nacro & Millogo-Rasolodimbi, 1993; Neuwinger, 2000; Palé, Nacro & Kouda-Bonafas, 1998; Zahan, 1951.

Sources of illustration Aubréville, 1950.

Authors M. Marquet & P.C.M. Jansen

LANNEA VELUTINA A.Rich.

Protologue Guill., Fl. Seneg. tent. 1(4): 154 (1831), 1(5): t. 42 (1832).

Family Anacardiaceae

Vernacular names Raisinier velu, Lannéa velouté (Fr). Bembo (Po).

Origin and geographic distribution *Lannea velutina* is found from Senegal to Chad and Central African Republic.

Uses The bark of *Lannea velutina* yields a popular red-brown dye. It is one of the main plants used in the production of the cloths called 'basilanfini', widely associated with the notion of healing, since the decoction of the plant is both medicinal and dyes the colour of blood. The wood, although whitish and soft, is considered suitable for making planks, small stools and other utensils, and as it is flexible, it is also used for bows. It is a preferred source of firewood in Burkina Faso. In Chad the wood is popular for making beehives since it is easy to hollow out. In Senegal macerated bark and roots are used medicinally to prepare a bath for rachitic children and adults with muscle pains. A decoction of the powdered root is used against diarrhoea. In Côte d'Ivoire the bark is used to treat diarrhoea, oedema, paralysis, epilepsy and insanity. In Ghana the bark is applied externally to wounds, ulcers and leprosy, and a decoction is taken against gastric pains. In Burkina Faso a decoction of the bark and leaves is used as a tonic, both as a drink and bath, because it is thought to control arterial tension. In Senegal the foliage is browsed by cattle and the fruit is said to be edible. Fibre isolated from the bark is used in Senegal to make ropes to tether goats and sheep. Sap of the bark is said to provide a good varnish.

Properties Tannins are present in the bark, together with reddish brown dyes that have not been characterized yet. *Lannea velutina* showed positive results in a test in Mali for antifungal, insecticidal (on larvae of mosquitoes), molluscicidal, antioxidant and radical scavenging activities.

Botany Dioecious tree up to 15 m tall; bole up to 45 cm in diameter, bark smooth, grey. Leaves alternate, pinnately compound with 3–5 pairs of opposite leaflets and a terminal one; stipules absent; petiole 2–5 cm long; leaflets elliptical, 4–12 cm × 3–7 cm, rounded at apex, entire, velvety tomentose below, lateral veins 10–18 pairs. Inflorescence a spike-like raceme up to 15 cm long, usually terminal on old branches (rarely on young shoots), brown-hairy. Flowers unisexual, regular, c. 5 mm long, 4-merous, greenish yellow; pedicel 2–4 mm long, elongating to 7–10 mm in fruit; male flowers with 8 stamens and rudimentary ovary; female flowers with superior, 4-celled ovary and rudimentary stamens. Fruit an ovoid to cylindrical drupe 8–10 mm × 6–7 mm, with 4 teeth at apex, densely softly pubescent, yellow-red.

Lannea comprises about 40 species, most of which are restricted to Africa. *Lannea velutina* flowers at the end of the dry season, before the appearance of the leaves.

Ecology *Lannea velutina* occurs in wooded savanna.

Management The bark is cut into small pieces and cooked for a long time. The cooled decoction is filtered and the cloth to be coloured is kept for 24 hours in the filtrate. The cloth colours red, red-brown or orange-red without any mordant.

Genetic resources and breeding *Lannea velutina* is rather widespread and does not seem to be in danger of genetic erosion.

Prospects *Lannea velutina* is an important source of red dye used in traditional dyeing in Africa. Interest in textiles coloured with natural dyes is growing and it is expected that the importance of *Lannea velutina* will increase. Its medicinal properties and possibilities for cultivation need further research.

Major references Arbonnier, 2004; Berhaut, 1971; Burkill, 1985; Burkill, 2000; Cardon, 2003.

Other references Diallo et al., 2001; Geerling, 1982; Irvine, 1961; Keay, 1958; Taïta, 2000.

Authors P.C.M. Jansen

LAWSONIA INERMIS L.

Protologue Sp. pl. 1: 349 (1753).

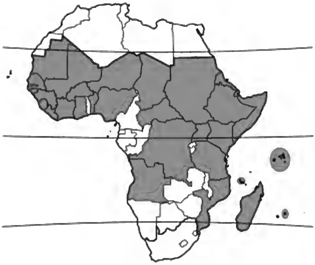
Family Lythraceae

Chromosome number $2n = 30$

Synonyms *Lawsonia alba* Lam. (1789).

Vernacular names Henna, Egyptian privet (En). Henné (Fr). Hena, hésia (Po). Mhina, muhina, (Sw).

Origin and geographic distribution The origin of *Lawsonia inermis* is unknown. Linguistic evidence supports an origin in the area of Baluchistan (Iran/Pakistan) to western India, where it can still be found growing in the wild. From there it would have spread eastward to the rest of India and Indonesia, and westward to the Middle East where it became one of the important plants of Islam. It was, however, already mentioned in the Bible for its



Lawsonia inermis – planted and naturalized

perfume ('kopher') and in Ancient Egypt ('kwpr'). It later followed Islamic armies and traders from Arabia reaching as far as Spain, northern Africa, Madagascar, the Moluccas, Indo-China and Japan. It is now distributed throughout the tropics and subtropics. Henna is mostly grown in home gardens and commercial production is limited to a few places in India, Pakistan, Iran, Egypt, Libya, Niger and Sudan. In Africa it has often become naturalized, particularly on alluvial soils along rivers. In Madagascar it has become so common along some rivers that there is no need for cultivation.

Uses Henna is one of the oldest cosmetics in the world and its leaves are used to colour the fingernails, to paint or decorate the palms of the hands and the soles of the feet, and to dye the hair. Written records of the use of henna date back more than 2500 years. Henna is of great importance in Islam, where it is used in many ceremonies, especially marriage. This latter use has been adopted also in Hinduism and Buddhism. The use of henna to dye the palms of the hands and the soles of the feet of married women has spread through most of the Muslim world and India. As part of the preparations for the marriage ceremony, the hands and feet of the bride are often very elaborately decorated, in the belief that henna purifies and protects; designs differ per region and culture, indicating for example good health, fertility, wisdom and spiritual enlightenment. In parts of Africa large, black, geometric designs are preferred. Henna is used universally as a basis for hair dyes. A wide range of shades from shining, reddish-blond to chestnut brown and intense, deep black can be obtained by the use of admixtures or by combining the treatment with other ones. Indigo is commonly added to obtain a black colour. This use of henna is not restricted to women. In Iran and Afghanistan men often use it to colour their greying hair and beards. It is even used to dye the manes and tails of horses of dignitaries for grand parades. Throughout South-East Asia and Indo-China up to Japan henna is mainly used by women as a dye for the fingernails, but in other areas this is only a secondary use.

To prepare the dye for skin, nails or hair, fresh or dried leaves or henna powder are rubbed with water to which some lemon juice and lime are added to obtain a paste. Depending on the use, the colour required and the locality, substances such as gambier, powder of areca nut, indigo or alum may be added. The paste is carefully applied to the skin or nails, or rubbed into the hair and left for 6–12 hours, covered with a damp cloth or sometimes a betel leaf. The colour is fast and cannot be removed by washing; it has to wear off. Henna was widely used to dye silk, wool and less commonly cotton, without mordanting or after a mordant bath, by putting the textiles in a hot bath of henna to which some lemon juice was added. Various orange and red colours could be obtained by adding other ingredients. This dye was often used as a ground, and then top-dyed with indigo to obtain a deep, fast black. Morocco leather is still dyed with henna.

The use of a perfume made from the flowers of henna is largely restricted to Egypt, northern India and Java. The perfume is greenish in colour and is prepared by macerating the flowers in oil (preferably oil of *Moringa peregrina* (Forssk.) Fiori ('ben'), which does not easily become rancid). Henna is widely grown in gardens as an ornamental or hedge plant, appreciated for the strong, pleasant fragrance of its flowers, which is reminiscent of tea rose (*Rosa chinensis* Jacq.). The wood of henna is fine grained and hard and has been used to make tent pegs and tool handles in India, but is also used as firewood. The fibres of branches and stem bark are used in Kenya to make baskets, small twigs as toothbrushes in Indonesia.

In traditional medicine henna is used as a panacea against almost any disease. Only the medicinal uses that have been confirmed in clinical tests are mentioned here. Extracts of the leaves have an astringent effect on the skin, making it somewhat hydrophobic. This effect, combined with a slight bactericidal and fungicidal action, makes it a useful medicine for external use against many skin and nail complaints. Dyeing hair with henna effectively kills lice. In Arabic and Indian medicine, preparations from the leaves, sometimes including other parts of the plant (root), are effectively used to promote childbirth, as an abortifacient and as an emmenagogue. A decoction of the leaves and roots is effective against certain forms of diarrhoea. In Côte d'Ivoire and northern Nigeria the leaves are used in the treatment of trypanosomiasis.

Production and international trade Because large quantities of henna are produced at home or for the local market, and because henna is mostly classified under categories that include several other products, it is impossible to obtain accurate estimates of production. Annual exports of powdered and dried leaves from India, Egypt and Sudan amounted to 6000–8000 t in the period 1975–1980. Total annual exports must be over 10,000 t and Dubai and Singapore are important entrepôts. The annual export from Sudan alone is estimated at 1000 t. World prices in 1992 fluctuated between 250–700 US$/t, depending strongly on quality and total supply. Demand for henna rose rapidly between 1960 and 1980, but has since levelled off. The main importers are the Arab countries (Saudi Arabia about 3000 t/year), France (250 t/year), Britain (100 t/year) and the United States (several hundred t/year). Traditionally Niger has an export link with Algeria.

In international trade, 3 henna grades are distinguished: green, black and neutral, but their composition is not always clear. Green henna is made from the young leaves, imparting a deep red colour. Black henna can be henna with a higher lawsone content in the leaves (it is the most expensive grade), but it can also be henna mixed with *Indigofera* leaves or the chemical compound paraphenylenediamine (PPD) to dye hair black. Neutral henna can be the lowest grade henna, but sometimes it is also used to indicate any natural hair colouring agent, e.g. leaves of *Senna italica* Mill. without any henna leaf.

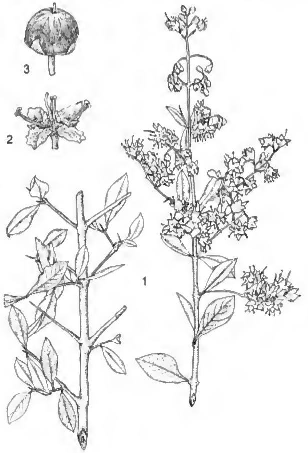
Properties The dyeing agent in henna is lawsone or 2-hydroxy-1,4-naphthoquinone (naphthalenedione), which is present in dry leaves at a concentration of 0.5–2%. It attaches itself strongly to proteins, and as a result the dye is very fast. Other components in henna such as flavonoids (luteoline, acacetine) and gallic acid contribute as organic mordants to the colouring process; carbohydrates (vegetable gelatine, mucilage) give the henna paste a suitable consistency to attach to hair and possibly they also play a role in the penetration of lawsone into the hair and other tissues. The stem contains variable amounts of tannins. On steam distillation, the flowers yield 0.01–0.02% essential oil (henna oil), mainly consisting of α- and β-ionones, which can be used as a basis for perfumes. The seeds contain about 10% of a non-drying, viscous oil, composed mainly of oleic, linoleic and stearic acids. This oil is not of commercial importance, but is used, for example in Uganda, for anointing the body.

Henna showed anti-inflammatory, analgesic and antipyretic effects, but it may cause side-effects such as haemolytic anaemia in cases of glucose-6-phosphate dehydrogenase enzyme deficiency. Tests with rats suggested hepatoprotective and anti-oxidant activities of bark extracts. Henna extracts also showed molluscicidal and trypanocidal activities. A leaf extract showed antitumour and tuberculostatic effects in tests with mice. It exhibited a broad fungitoxic spectrum when tested against various ringworm fungi, which was attributed to lawsone. In India henna preparations showed antifertility activity.

Adulterations and substitutes Adulteration of dried, entire henna leaves is almost impossible because it is easy detectable. Commercially low quality henna leaves often contain a high percentage of rubbish in the form of parts of branches, fruits and other plants. Most adulteration occurs in powdered henna and includes powdered leaves of other species, sand, powdered shells and colorants, and microscopic analysis is needed, looking for details which cannot be present in true henna. Colorants are used to falsify the henna quality. Often used colorants are diamond green and auramine yellow, although both colorants are forbidden in foods and medicines.

Sometimes the term henna is used to indicate any hair colouring agent, often without any link with true henna. Numerous natural and chemical products are used in combination with henna, e.g. to modify the hair colour (walnut husk, logwood, turmeric, indigo, lucerne, tea, mordants, tannins, synthetic colorants), to improve the colouring (walnut husk, chamomile, lucerne, onion skin, sage, senna), as perfume (flower buds of *Myrtus communis* L., cloves, rose water) or to improve the penetration of the colorant (e.g. lemon juice, sour milk or beer yeast). Paraphenylenediamine in 'black henna' may cause serious irritation and burning of the skin.

Description Much-branched, glabrous shrub or small tree up to 6(–12) m tall, with greyish-brown bark and quadrangular young branches, older plants sometimes with spine-tipped branchlets up to 3.5 cm long. Leaves decussately opposite, simple and entire, almost sessile; stipules minute; blade elliptical to oblong or broadly lanceolate, 1–8.5 cm × 0.5–4 cm, cuneate at base, acute to rounded at apex, pinnately veined. Inflorescence a large, pyramidal, terminal panicle up to 25 cm long, many-flowered. Flowers bisexual, regular, 4-merous, sweet-scented; pedicel 2–4 mm long; calyx with up to 2 mm long tube and spreading, ovate lobes 2–3 mm long; petals orbicular to obovate, 1.5–4 mm × 4–5 mm, usually whitish, sometimes reddish; stamens 8, inserted in pairs on the rim of the calyx tube, filaments 4–5 mm long; ovary superior, 4-celled, style erect, up to 5 mm long, stigma head-shaped. Fruit a globose capsule 4–8 mm in diameter, purplish-green, indehiscent or opening irregularly, many-seeded. Seeds 4-angular, 2–3 mm long, with thick seedcoat.



Lawsonia inermis – 1, lower and upper part of flowering branch; 2, flower; 3, fruit.
Source: PROSEA

Other botanical information *Lawsonia* comprises only 1 species. Henna cultivars can be white- and red-flowered, large-leaved and small-leaved. It is often stated that small-leaved henna is of better quality and more effective than larger-leaved. Small-leaved cultivars include 'Filalia' and 'Touatia' in Morocco and 'Gabsia' in Libya and Tunisia. 'Trabelsia' is a large-leaved cultivar. The leaf size is also dependent on the availability of water. In the dry season and in dry locations the leaves can be 5–6 times smaller than in the rainy season or in wet locations.

Growth and development Henna can grow to the size of a large shrub or even small tree, but is normally grown like lucerne (*Medicago sativa* L.), i.e. as a short-lived perennial crop up 70 cm tall.

Ecology Henna requires high temperatures (optimum daily average about 25°C) for germination, growth and development. It is adapted to a wide range of conditions. It tolerates poor, stony and sandy soils, but is also well adapted to heavy, fertile clay soils. Low air humidity and drought are tolerated. Naturalized plants are often found in temporarily flooded river beds and riverine thickets, but also on hillsides and in rock crevices, up to 1350 m altitude.

Propagation and planting When grown commercially, henna is either grown from seed and transplanted, or propagated by cuttings or micropropagated plants. In northern Africa land is prepared carefully by ploughing up to 40 cm deep, and heavily manuring. Fields are then levelled and prepared for basin irrigation. In India, where production is less intensive, land is only ploughed a few times. Because of its hard seedcoat, henna seeds have to be pre-germinated before sowing. They are first steeped in water for 3–7 days, during which time the water is changed daily. They are then placed in small heaps and kept moist and warm for a few days. Care is taken to drain excess water. When the seedcoat has softened and the seed has started to swell, it is ready to be sown in a nursery. During the first days after sowing, the soil should be kept moist and daily irrigations are often required. When the plants are about 40 cm tall they are lifted, cut back to about 15 cm and transplanted. Planting densities range widely from 20,000 to 200,000 plants/ha, depending on water availability. An amount of 3–5 kg of seed per ha is needed. For propagation by cuttings, branches with 6–8 buds are used.

Management Under intensive commercial production, as in northern Africa, the crop is irrigated during the dry season and heavily fertilized. In India it is grown on a larger scale, less intensively, often without irrigation and rarely fertilized. Fields are hoed once or twice per year and weeded when required. Plants produce their maximum yields during the first 4–8 years after planting, but are often left in the field for 12–25(–40) years. Henna removes large quantities of nutrients from the soil. A yield of 1000 kg dry leaves removes 180–190 kg N, 100–150 kg K_2O and 10–30 kg P_2O_5.

Diseases and pests Very few pests and diseases attack henna. A black root rot caused by *Corticium koleroga* and a bacterial leaf-spot caused by *Xanthomonas lawsoniae* have been reported from western India.

Harvesting Plants are generally harvested 2–4 times per year from the second year onwards under intensive cultivation. Harvesting starts 1 or 2 years later under extensive management. At the first harvest plants are cut at about 10–15 cm above the ground, later they are cut at ground level. Harvesting is done when the flower buds start to form.

Yield Few reliable statistics on yields are available. Under irrigation, henna may yield 2500–3000 kg/ha per year of leaves on dry weight basis, reaching 4000 kg/ha under optimal conditions. Under rainfed conditions in northern India yields of 700–1500 kg/ha are obtained.

Handling after harvest In many regions fresh leaves are picked from the home garden when needed and used fresh. In the Arab world and India, leafy branches are harvested, left to dry, and the leaves are separated from the branches by beating; the dry sticks may be left around the field as fencing. Drying (to about 10% water content) should be rapid and preferably in the shade to retain the green colour of the leaves, which is an indication of good quality. Dried green leaves are preferred for hand and foot colouring, brownish leaves (dried less quickly) for hair colouring. Because of the better drying conditions, leaves harvested during the hot dry season are of better quality than those from the rainy season. For export, dried leaves are packed into bales of 50 kg (to western Europe) or powdered leaves in cartons of 25–50 kg with 100–500 g sachets for direct retail sale (to Middle East markets). Dried leaves are preferred by most traders, as they are less easily adulterated. Quality and purity demands differ strongly per country and per intended use. If the odour also plays a role, a mixture of leaves and flowers is preferred; if black colouring is needed, leaves mixed with indigo are preferred. In all cases, henna should be stored dry in the dark.

Genetic resources Germplasm collections of henna are not known to exist. Germplasm collection is recommended to safeguard the wide genetic variation present in traditional cultivars, often associated with the location of production.

Breeding Breeding should focus on reliable cultivars with high yield and quality for various ecological circumstances.

Prospects The very low toxicity of henna and its strongly rooted traditions make it one of the few natural dyes for which demand is still considerable. The ongoing search for innocuous natural dyes may add to its present uses. With more attention given to the selection of cultivars with a high lawsone content and to the development of better drying and processing techniques, it should be possible to expand commercial henna production to more humid areas. Commercial production should be possible in most African countries, but much attention needs to be paid to quality, packaging requirements and trading structures.

Major references Aubaile Sallenave, 1982; Burkill, 1995; Cardon, 2003; Green, 1995; Kolarkar, Singh & Shankarnarayanan, 1981; Lemordant & Forestier, 1983a; Lemordant & Forestier, 1983b; Oyen, 1991a; Scarone, 1939; Verdcourt, 1994.

Other references Beentje, 1994; Boutique, 1967; CSIR, 1962; Decary, 1946; Fernandes, 1978b; Gilbert & Thulin, 1993; Gilbert, 2000; Gurib-Fakim, Guého & Bissoondoyal, 1996; Keay, 1954b; Kerharo & Adam, 1974; Kokwaro, 1993; Perrier de la Bathie, 1954; Watt & Breyer-Brandwijk, 1962; Wolf et al., 2003.

Sources of illustration Oyen, 1991a.

Authors Getachew Aweke & Suzanne Tapapul Lekoyiet

Based on PROSEA 3: Dye and tannin-producing plants.

LUDWIGIA LEPTOCARPA (Nutt.) H.Hara

Protologue Journ. Jap. Bot. 28: 292 (1953).

Family Onagraceae

Chromosome number *n* = 24

Synonyms *Jussiaea leptocarpa* Nutt. (1818), *Jussiaea pilosa* Kunth (1823), *Jussiaea seminuda* H.Perrier (1947).

Vernacular names Anglestem primrose willow, hairy primrose willow (En). Jussie (Fr). Cruz de malta (Po). Mniza, mng'iza (Sw).

Origin and geographic distribution *Ludwigia leptocarpa* originates most probably from the New World, where it occurs from the United States and the West Indies south to Peru and Argentina. In the Old World it is found all over tropical Africa and Madagascar.

Uses The leaves of *Ludwigia leptocarpa* are collected from the wild and yield a black dye used in East Africa (Pemba, Tanzania) to blacken mats, baskets and bags made of palm leaves. In the Central African Republic the whole plant is burnt to produce a vegetable salt. In traditional medicine in Nigeria an infusion is part of a mixture to treat rheumatism. A leaf infusion has laxative, vermifugal and anti-dysenteric properties. In Nigeria its invasive habit as a colonizer of dried-up stream beds and similar damp locations has been found useful in erosion control.

Properties No research on the components responsible for the black colouring properties of *Ludwigia leptocarpa* has been published, but the presence of the glycoflavones vitexin, isovitexin, orientin and isoorientin has been reported.

Botany Erect, robust, hairy, annual herb up to 3 m tall, sometimes somewhat woody below, much branched, often submerged and then with erect flowering branches and floating pneumatophores arising from the roots. Leaves alternate, simple and entire; stipules absent or reduced; petiole 0–2 cm long; blade lanceolate, sometimes elliptical, 3–15 cm × 1–4 cm, base cuneate, apex acute to acuminate. Flowers solitary, bisexual, regular, (4–)5(–7)-merous; pedicel c. 2 mm long (in fruit up to 2 cm); sepals triangular, up to 10 mm × 3 mm; petals obovate, up to 11 mm × 8 mm, yellow; stamens usually 10, filaments up to 4 mm long; ovary inferior, 4–5-celled, style up to 4.5 mm long, stigma head-like, up to 2.5 mm in diameter. Fruit a capsule, cylindrical in lower part, usually 5-angled in upper part, 1.5–5 cm × 2.5–4 mm, long-hairy, slowly dehiscent, brown-purple, many-seeded. Seeds ovoid, c. 1 mm long, pale brown, surrounded by a horseshoe-shaped piece of powdery endocarp which is easily detached and with a narrow white raphe. Seedling with epigeal germination.

Formerly a distinction was made between *Jussiaea* (stamens twice as numerous as the sepals) and *Ludwigia* (stamens as many as the sepals), but now *Jussiaea* is considered synonymous with *Ludwigia*, comprising about 75 species with 8 species endemic in Africa.

Ecology *Ludwigia leptocarpa* grows in swamps and along rivers, lakes and ponds, from sea-level up to 1900 m altitude. In irrigated rice fields it can become a troublesome weed.

Genetic resources and breeding *Ludwigia leptocarpa* is very widespread and not in danger of genetic erosion. In South America its population behaviour and genetics are being studied.

Prospects *Ludwigia leptocarpa* as source of a dye is only locally of some importance. For a better understanding, its dye and medicinal properties need further research.

Major references Bizzarri, 2000; Burkill, 1997; Williams, 1949.

Other references Averett, Zardini & Hoch, 1990; Brenan, 1953; Brenan, 1954; Isa Ipor, 2001; Ormond et al., 1978; Raven, 1963; Raven, 1978; Raynal, 1966.

Authors P.C.M. Jansen

MORINDA LUCIDA Benth.

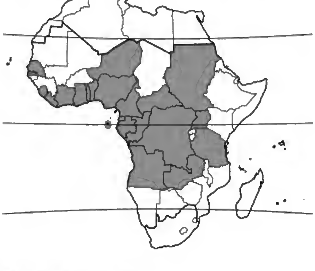
Protologue Hook., Niger Fl.: 406 (1849).

Family Rubiaceae

Vernacular names Brimstone tree (En). Arbre à soufre, oruwo (Fr). Moindo (Po).

Origin and geographic distribution *Morinda lucida* occurs from Senegal to Sudan and southward to Angola and Zambia. It is sometimes planted around villages, e.g. in Benin.

Uses The wood of *Morinda lucida* yields yellow to red dyes. In Nigeria and Gabon the root bark is used to dye textiles into scarlet red. On occasions of national grief or the death of a chief, the Ashanti people of Ghana dye cotton cloths red with the root bark of *Morinda*



Morinda lucida – wild

lucida. These cloths, called 'kobene', are worn as mourning dress by official people and by the family of the deceased. The root is the most important traditional source of yellow dye for textiles in the Kasai Province of DR Congo. It can be used without a mordant. The root is also added to indigo vats in Côte d'Ivoire, to contribute both to the fermentation and reduction process necessary for dyeing with indigo and to get darker blues. In this process it is often combined with leafy twigs of *Saba comorensis* (Bojer) Pichon (synonym: *Saba florida* (Benth.) Bullock). In the region of Kasongo in north-eastern DR Congo, young leaves of *Morinda lucida* are combined with leaves of a *Philenoptera* species (a source of indigo) to obtain a pale green dye used in basket weaving. The bitter-tasting roots are used as flavouring for food and alcoholic beverages and in Nigeria they are popular as chewing sticks. The wood is excellent for making charcoal, but is also used for construction, mining props, furniture, canoes, poles and fuelwood. The leaves are used for cleaning and scouring, e.g. of calabashes. In West Africa *Morinda lucida* is an important plant in traditional medicine. Decoctions and infusions or plasters of root, bark and leaves are recognized remedies against different types of fever, including yellow fever, malaria, trypanosomiasis and feverish condition during childbirth. The plant is also employed in cases of diabetes, hypertension, cerebral congestion, dysentery, stomach-ache, ulcers, leprosy and gonorrhoea. In Nigeria *Morinda lucida* is one of the 4 most used traditional medicines against fever. In Côte d'Ivoire a bark or leaf decoction is applied against jaundice and in DR Congo it is combined with a dressing of powdered root bark against itch and ringworm.

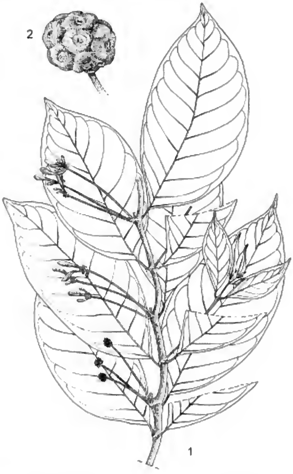
Production and international trade In West Africa the roots of *Morinda lucida* are for sale in local shops and markets, both as dyestuff and medicine, but statistics on quantities involved are not available. Leaves and twigs are sold in markets as a medicinal tonic for young children.

Properties From the wood and bark of *Morinda lucida* 18 anthraquinones have been isolated, including the red colorants 1-methylether-alizarin, rubiadin and derivatives, lucidin, soranjidiol, damnacanthal, nordamnacanthal, morindin, munjistin and purpuroxanthin. Two anthraquinols, oruwal and oruwalol, have also been found; these give a yellow colour and possibly are intermediates in the formation of anthraquinones. In addition to anthraquinones, tannins, flavonoids and saponosides have been isolated.

The wood is yellow (hence the name brimstone tree), darkening to yellow-brown in the sapwood and to dark brown in the heartwood. It is medium-weight and hard; it works and finishes well, and it is durable, being resistant to fungi, termites and other insects.

Tests with animals confirm the attributed activity of several traditional medicinal applications of *Morinda lucida*. Extracts showed anti-inflammatory, antifever and pain-reducing activity in tests with rats and promoted gastric emptying and intestinal motility. Leaf extracts showed in vitro antimalarial activity against *Plasmodium falciparum* while in several other tests antidiabetic properties were confirmed. Inhibiting effects on cancer tumours in mice have also been reported. A leaf extract gave 100% mortality in the freshwater snail *Bulinus globulus* at a concentration of 100 ppm.

Description Evergreen shrub or small to medium-sized tree up to 18(–25) m tall, with bole and branches often crooked or gnarled;



Morinda lucida – 1, flowering branch; 2, infructescence.
Redrawn and adapted by Achmad Satiri Nurhaman

bark smooth to roughly scaly, grey to brown, often with some distinct purple layers. Leaves opposite, simple and entire; stipules ovate or triangular, 1–7 mm long, falling early; petiole up to 1.5 cm long; blade elliptical, 6–18 cm × 2–9 cm, base rounded to cuneate, apex acute to acuminate, shiny above, sometimes finely pubescent when young, later only tufts of hairs in vein axils beneath and some hairs on the midrib. Inflorescence a stalked head 4–7 mm in diameter, 1–3 at the nodes opposite a single leaf; peduncle up to 8 cm long bearing at base a stalked cup-shaped gland. Flowers bisexual, regular, 5-merous, heterostylous, fragrant; calyx cup-shaped, c. 2 mm long, persistent; corolla salver-shaped, c. 1.5 cm long, white or greenish yellow, lobes ovate-lanceolate, up to 5 mm × 2.5 mm; ovary inferior, 2-celled, style 8–11 mm long with 2 stigma lobes 4–7 mm long; stamens 5, inserted in the corolla throat, with short filaments. Fruit a drupe, several together arranged into an almost globose succulent syncarp 1–2.5 cm in diameter, soft and black when mature; pyrene compressed ovoid, up to 6.5 mm × 4 mm, dark red-brown, very hard, 1-seeded. Seed ellipsoid, c. 3.5 mm × 2 mm × 0.5 mm, yellowish, soft.

Other botanical information *Morinda* comprises about 80 species and occurs throughout the tropics. In Africa 5 species are found. The comparatively small flowering and fruiting heads on long slender peduncles are distinctive characteristics of *Morinda lucida*. Other *Morinda* species also yield yellow and red dyes, but they usually have other more important uses. Many species, including those from Africa, are important medicinal plants, widely applied against various kinds of fevers and infections. The powerful dye from bark and roots of *Morinda citrifolia* L. is used where traditional textile dyeing is practised in Africa. The root bark of *Morinda geminata* DC. is used in Côte d'Ivoire to dye traditional cotton cloth bright orange-red and the bark is also added to indigo baths to promote fermentation and to produce darker blue colours. From the root bark of *Morinda longiflora* G.Don the red anthraquinone colorants 1-methylether-alizarin and rubiadin have been isolated and the leaves and roots of *Morinda morindoides* (Bak.) Milne-Redh. also contain anthraquinone compounds used for red colouring.

Growth and development In Côte d'Ivoire flowering of *Morinda lucida* is from February to May, fruiting from April to June.

Ecology *Morinda lucida* grows in grassland, exposed hillsides, thickets, forests, often on termite mounds, sometimes in areas which are regularly flooded, from sea-level up to 1300 m altitude.

Management The useful parts of *Morinda lucida* are mostly collected from wild plants. Only occasionally are plants grown in home gardens. Propagation is possible by seed and cuttings, but no details are known.

Handling after harvest For dyeing, the root bark or leaves are used fresh, pounded or chopped. For red colours, the fibres to be dyed must first be mordanted with tannin-containing plants and alum. For red and yellow colours, the dye baths are prepared by boiling the root bark or leafy twigs in water for one or two hours before filtering and plunging the textiles into the coloured liquid and boiling it again until the desired shade is obtained.

Genetic resources *Morinda lucida* is widespread in Africa and not in danger of genetic erosion. Germplasm collections are not known to exist.

Prospects *Morinda lucida* is an interesting multipurpose species yielding dyes, timber, fuel and traditional medicines. For a reliable evaluation, however, more research is needed on its chemical composition and cultivation possibilities.

Major references Abbiw, 1990; Adesida & Adesogan, 1972; Burkill, 1997; Cardon, 2003; Hepper & Keay, 1963; Irvine, 1961; Miège, 1992; Staner, 1936; Verdcourt, 1976; Verdcourt, 1989.

Other references Asuzu & Chineme, 1990; Aubréville, 1950; Awe & Makinde, 1998; Awe et al., 1998; Dalziel, 1937; Koumaglo et al., 1992; Makinde & Obih, 1985; Neuwinger, 2000; Obih, Makinde & Laoye, 1985; Olajide, Awe & Makinde, 1998.

Sources of illustration Pauwels, 1993.

Authors C. Zimudzi & D. Cardon

MUCUNA FLAGELLIPES Hook.f.

Protologue Niger fl.: 307 (1849).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Origin and geographic distribution *Mucuna flagellipes* occurs from Sierra Leone east to Central African Republic, DR Congo, and south to Angola. Its reported occurrence in Uganda is doubtful.

Uses Vegetable fibres and cloth, leather, wooden objects and pottery are dyed black or blue-black by boiling them up with stems and leaves of *Mucuna flagellipes*, often together with the fruits of *Alchornea cordifolia* (Schumach. & Thonn.) Müll.Arg. (*Euphorbiaceae*), both collected from the wild. The leaf sap is used fresh as blue-black dye for bark cloth ('pongo') by the Mbuti Pygmies of the Ituri Forest in north-eastern DR Congo. The stems, branches and flower stalks are used as a rough fibre (e.g. as rope) and the seeds in games. In Côte d'Ivoire a decoction of leafy twigs is used as a beverage or a bath to treat rachitic children, and it is also taken as an emmenagogue and to stop diarrhoea. In Nigeria the hairs on the fruit, which intensely irritate the skin, are used in a medicine to expel tapeworm. The cotyledons are eaten raw against slipped disc. The pulverized fruits are applied against lice. The gum present in the seeds is an emulsifying and suspending agent and is, for example, applied in pharmacology to prepare suspensions of sulphadimine and zinc oxide and in bread baking to improve moisture retention and to reduce crumb firmness.

Properties Tannins, cyanogenic glycosides and indolic alkaloids have been reported in various *Mucuna* species and may all contribute to the colouring effect of the sap and leaves. *Mucuna flagellipes* seed contains approximately 20% protein and 70% carbohydrate. The carbohydrate consists for up to 50% of a water-dispersible polysaccharide (gum), which has a high pseudoplasticity. The major monosaccharide is D-galactose. The seeds probably also contain the amino acid L-dopa.

Botany Large liana up to 12 m long with stem up to 3 cm in diameter, glabrous. Leaves alternate, pinnately 3-foliolate; stipules deciduous; petiole 4–11 cm long, rachis up to 3.5 cm long; petiolules up to 7 mm long; leaflets ovate to oblong-elliptical, 7–14 cm × 3–7 cm, rounded to slightly cordate at base, apex acuminate. Inflorescence an axillary, pendent, silvery hairy raceme with zigzag rachis up to 20 cm long; peduncle up to 3 cm long. Flowers bisexual, papilionaceous, showy; pedicel up to 5 cm long in fruit; calyx campanulate, 2-lipped, up to 3 cm long, tube and 4 lobes of about equal length, densely appressed pubescent with orange-brown bristles; corolla cream or greenish-white, standard rounded, up to 4 cm × 4 cm, with a median claw and a pair of inflexed lateral auricles at base, wings and keel up to 4.5 cm long, clawed and with a small auricle; stamens 10, 1 free and the other 9 fused; ovary superior, 1-celled, style long. Fruit a pod up to 19 cm × 6 cm × 2 cm, with about 12 interrupted transverse wing-like ridges, densely covered with red-brown irritant hairs, usually 2–4-seeded. Seeds discoid with convex faces, up to 3 cm × 3 cm × 2 cm, purple, distinctly rough.

Mucuna belongs to the tribe *Phaseoleae* and is a large genus comprising about 100 species, distributed pantropically. In tropical Africa about 10 species are present. The hairs on the fruits, which irritate the skin intensely, make the plants difficult to handle.

Ecology *Mucuna flagellipes* is found in wet shaded localities in riverine and swamp forests and at the borders of mangrove vegetation, from sea-level up to 1400 m altitude. Flowering and fruiting occur yearround.

Genetic resources and breeding *Mucuna flagellipes* is widespread and not in danger of genetic erosion.

Prospects *Mucuna flagellipes* will remain only locally of importance for black or blue dyeing of clothes, wickerwork, pottery and wooden utensils. Ease of application, direct effect and intense coloration on various substrates using the leaf sap makes research on the indolic alkaloids in *Mucuna* spp. worthwhile, e.g. to investigate possible applications as cosmetic colorants.

Major references Abbiw, 1990; Burkill, 1995; Gillett et al., 1971; Irvine, 1961; Staner, 1936; Tanno, 1981.

Other references Dahal & van Valkenburg, 2003; Ghosal, Singh & Bhattacharya, 1971; Hauman et al., 1954; Hepper, 1958; Neuwinger, 2000; Onweluzo, Obanu & Onuoha, 1994; Onweluzo, Leelavathi & Rao, 1999; Raponda-Walker & Sillans, 1961; Szabo & Tebbett, undated.

Authors P.C.M. Jansen

MUCUNA POGGEI Taub.

Protologue Bot. Jahrb. 23: 194 (1896).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Synonyms *Mucuna rubro-aurantiaca* De Wild. (1913), *Mucuna pesa* De Wild. (1914).

Vernacular names Buffalo bean (En). Mucuna de Pogge (Fr). Kihuta (Po).

Origin and geographic distribution *Mucuna poggei* is distributed all over tropical Africa, but does not occur in the Indian Ocean islands.

Uses In Togo the stems of *Mucuna poggei*, collected from the wild, are used to prepare a black dye and in the south of DR Congo (Katanga) a black ink is prepared from the leaf sap. In DR Congo pounded stems are cast into streams to stupefy fish and the ash is used to chase snakes. The thinner branches are used for tying. The seeds are edible and in Nigeria the plant is browsed by cattle. A decoction of the stem is said to cure spear wounds. Crushed bark and leaves are astringent and applied as a poultice to sores, wounds and burns. A root decoction or extract is used to treat dysentery, diarrhoea, malaria, gonorrhoea, hookworm and schistosomiasis. Root shavings are applied as an analgesic against toothache. In Mali a leaf decoction or young leaves are applied externally against herpes. A root decoction is used as a wash to treat paralysis of the legs and yellow fever. A flower decoction is applied in Tanzania against headache.

Properties *Mucuna poggei* stains hands and iron implements brown-red. Sap of the stem is dark brown and becomes dark red as it coagulates upon exposure to air. The chemical constituents are unknown. Tannins, cyanogenic glycosides and indolic alkaloids have been reported in various *Mucuna* species and may also be present in this species, contributing to the colouring effect of the sap and leaves. The seeds may also contain the amino acid L-dopa (levodopa).

Botany Large liana up to 30 m long with stem up to 20 cm in diameter, glabrous or pubescent. Leaves alternate, pinnately 3-foliolate; stipules triangular, c. 1 cm long, deciduous; petiole up to 16 cm long, rachis up to 3 cm long; petiolules up to 8 mm long; leaflets rhomboid, ovate or obovate, 10–19 cm × 6–19 cm, base rounded to slightly cordate, apex apiculate or rounded, lateral leaflets very asymmetrical, sparsely appressed pubescent above, densely silvery-grey hairy below. Inflorescence an axillary, pendent, grey to reddish hairy, many-flowered raceme; peduncle up to 20 cm long, rachis up to 32 cm long. Flowers bisexual, papilionaceous; pedicel up to 1 cm long; calyx campanulate, 2-lipped, tube 5–12 mm long, 4 lobes unequal, 2–7(–22) mm long, upper pair joined, densely velvety with bristly, irritant, orange-red hairs; corolla greenish white or yellowish, standard ovate to elliptical, c. 5 cm × 3 cm, wings and keel up to 9 cm long; stamens 10, 1 free and 9 united; ovary superior, 1-celled, style long. Fruit a circular to oblong pod 5–20 cm × 3.5–4 cm × 2 cm, densely covered with deciduous, orange-red, bristly, very irritant hairs, 1–5-seeded. Seeds irregularly elliptical-oblong, curved, compressed, up to 2.5 cm × 2 cm × 1 cm, purple or pale brown with dense dark brown mottling.

Mucuna belongs to the tribe *Phaseoleae* and is a large genus comprising about 100 species, distributed pantropically. In tropical Africa about 10 species are present. *Mucuna poggei* is rather variable and mainly based on corolla length and hairiness of the leaflets, several varieties have been distinguished.

Ecology *Mucuna poggei* is found in riverine and swamp forest, in bushland and in thickets, from sea-level up to 2000 m altitude.

Genetic resources and breeding *Mucuna poggei* is widespread and not in danger of genetic erosion.

Prospects *Mucuna poggei* will probably remain a minor dye source, only locally used. Its irritating bristly hairs on flowers and fruits make it difficult to handle. Nevertheless, the dye and tannin content and pharmacological properties of this and other African *Mucuna* species deserve research.

Major references Burkill, 1995; Gillett et al., 1971.

Other references Adjanohoun et al., 1979; Dahal & van Valkenburg, 2003; Haerdi, 1964; Hauman et al., 1954; Hepper, 1958; Neuwinger, 2000; Staner, 1936; Vergiat, 1970.

Authors P.C.M. Jansen

MUCUNA SLOANEI Fawc. & Rendle

Protologue Journ. Bot. 55: 36 (1917).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Synonyms *Mucuna urens* auct. non (L.) Medik.

Vernacular names Horse-eye bean, hamburger bean (En). Œil de bourrique, grand pois pouilleux (Fr).

Origin and geographic distribution *Mucuna sloanei* is very widespread, in Africa from Sierra Leone east to DR Congo, and south to Angola, also in the Caribbean region, tropical America and islands of the Pacific Ocean. Occasionally it is cultivated, e.g. in Nigeria.

Uses A black dye is obtained from all parts of *Mucuna sloanei*, which is used in Nigeria to dye fibre and leather black. Cooked young fruits are eaten as a vegetable; in Nigeria *Mucuna sloanei* is occasionally cultivated for that purpose. The ripe seed is eaten pounded and cooked, preferably in soups. Oil extracted from the seed can be used in the preparation of resin, paint, polish, wood varnish, skin cream and liquid soap. The Edo people in Nigeria use leaf sap to stop diarrhoea. In tropical America the seed is used as a diuretic, and in Gabon and tropical America a seed decoction is used as a soothing medicine to relieve the discomfort of haemorrhoids. The seeds are also used for decoration and in games.

Properties The dye of *Mucuna sloanei* has not been studied, but tannins, cyanogenic glycosides and indolic alkaloids have been reported in various *Mucuna* species and may also be present in this species, contributing to the colouring effect of the sap and leaves. Total lipid content of dry matter of *Mucuna sloanei* seed is about 7% (a different source gives an oil content of dried seeds of about 23%). Of the fatty acids, 83% is palmitic acid, oleic acid or linoleic acid. The dried seeds also contain (3%) of the amino acid L-dopa (levodopa), which stimulates the formation of the neurotransmitter dopamine in the brain.

Botany Liana up to 6 m long, with angular almost glabrous branches. Leaves alternate, pinnately 3-foliolate; stipules caducous; petiole 5–11 cm long, rachis 2–3 cm long; petiolules 3–4 mm long; leaflets ovate to elliptical, 7–11 cm × 4–7 cm, apex acuminate, lateral leaflets asymmetrical, silky pubescent below. Inflorescence an axillary, umbellate raceme, 5–10-flowered. Flowers bisexual, papilionaceous; pedicel c. 1 cm long; corolla up to 7 cm long, yellow-green to whitish yellow; stamens 10, 1 free and 9 united; ovary superior, 1-celled, style long. Fruit a flattened-cylindrical pod 10–14 cm × 4–5 cm × 1 cm, blackish, with 12–15 transversal deep furrows, bearing yellowish stinging hairs, 2–3-seeded. Seeds discoid, c. 3 cm in diameter and 2 cm thick, blackish to dark brown.

Mucuna belongs to the tribe *Phaseoleae* and is a large genus comprising about 100 species, distributed pantropically. In tropical Africa about 10 species are present.

Ecology *Mucuna sloanei* is found in wet localities in swamp forests, at borders of rivers and lakes, in savanna woodland and secondary vegetation.

Management In Nigeria cultivation of *Mucuna sloanei* is done using tall poles, as for climbing types of common bean.

Genetic resources and breeding *Mucuna sloanei* is widespread and not in danger of genetic erosion.

Prospects *Mucuna sloanei* will probably remain of minor importance locally as a source of black dye. Ease of application, direct effect and intense coloration on various substrates using the leaf sap makes research worthwhile, e.g. to investigate possible applications as cosmetic colorants. The nutritional and medicinal values of *Mucuna sloanei* also need further investigation.

Major references Burkill, 1995; Hauman et al., 1954; Irvine, 1961.

Other references Ajiwe et al., 1997; Eyo & Abel, 1979; Hepper, 1958; Rai & Saidu, 1977; Raponda-Walker & Sillans, 1961; Stevels, 1990; Szabo & Tebbett, undated.

Authors P.C.M. Jansen

PAURIDIANTHA RUBENS (Benth.) Bremek.

Protologue Bot. Jahrb. 71: 215 (1940).

Family Rubiaceae

Synonyms *Urophyllum rubens* Benth. (1849).

Origin and geographic distribution *Pauridiantha rubens* is found in Cameroon, Central African Republic, Equatorial Guinea, Gabon and DR Congo.

Uses Young leaves of *Pauridiantha rubens* yield a red dye, which is used in Bioko (Equatorial Guinea) and for which the plant is cultivated there. How the dye is used is not reported.

Properties The nature of the red dye present in the leaves of *Pauridiantha rubens* has not been studied. Several alkaloids have been identified in related species: harman, pauridianthin and pauridianthinin in the root bark of *Pauridiantha callicarpoides* (Hiern) Bremek., and pauridianthin and pauridianthinol in *Pauridiantha lyalii* Bremek. The dye potential of *Pauridiantha rubens* is optimized by the mordanting effect of the aluminium present in the leaves. Aluminium accumulation in leaves seems to be a chemotaxonomic characteristic of the *Pauridiantha* genus.

Botany Shrub or small tree up to 7 m tall, almost glabrous, with stem up to 15 cm in diameter. Leaves opposite, simple and entire; stipules up to 25 mm × 14 mm, normally persistent but falling near inflorescences; petiole up to 3.5 cm long; blade elliptical, 12–32 cm × 5–15 cm, base acute, apex acuminate, midrib very prominent below, young leaves brownish above, red below. Inflorescence an axillary panicle up to 4 cm long, solitary or in pairs; peduncle 1–1.5 cm long. Flowers bisexual, regular, 5-merous; pedicel up to 4 mm long; calyx cupular, truncate at apex or with small teeth; corolla white-green to green, tubular with triangular lobes up to 2 mm long; stamens short; disk c. 2 mm in diameter; ovary inferior, 2-celled, style c. 3 mm long, ending in 2 stigmatic lobes. Fruit a flattened globose berry up to 5 mm × 8 mm, many-seeded. Seeds c. 1 mm long.

Pauridiantha comprises about 25 species, all African (1 in Madagascar).

Ecology *Pauridiantha rubens* is found at forest edges and edges of clearings, from sea-level up to 500 m altitude.

Genetic resources and breeding *Pauridiantha rubens* is widespread and does not seem to be in danger of genetic erosion.

Prospects The use of the young leaves of *Pauridiantha rubens* as source of a red dye may remain only locally of some importance, but in the present conjuncture of renewed interest in natural dyes as renewable sources of non-polluting colorants, the combination in the same plant of a red dye and a mordant because of the presence of aluminium makes *Pauridiantha rubens* interesting, especially since it has been or still is cultivated. Methods of cultivation, chemical composition and traditional dye processes therefore deserve further investigation.

Major references Bremekamp, 1941; Burkill, 1997; Hallé, 1966; Jansen et al., 2000.

Other references Hepper & Keay, 1963; Hiern, 1877; Khan et al., 2004; Levesque, Jacquesy & Foucher, 1982; Pousset et al., 1971.

Authors P.C.M. Jansen

PHILENOPTERA CYANESCENS (Schumach. & Thonn.) Roberty

Protologue Bull. Inst. Franç. Afr. Noire, Sér. A, 16(2): 354 (1954).

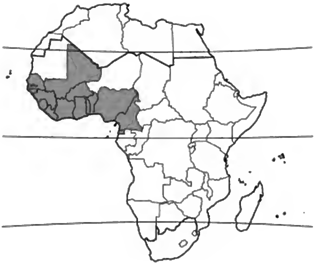
Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Chromosome number $2n = 22$

Synonyms *Lonchocarpus cyanescens* (Schumach. & Thonn.) Benth. (1860).

Vernacular names Gara, West African wild indigo, Yoruba indigo (En). Gara, liane-indigo (Fr).

Origin and geographic distribution *Philenoptera cyanescens* is widespread in western Africa, from Senegal to Cameroon and Equatorial Guinea (Bioko). It is also cultivated, particularly in Sierra Leone and Ghana, and occasionally elsewhere in the tropics.



Philenoptera cyanescens – wild

Uses All aerial parts of *Philenoptera cyanescens* yield an indigo dye used in West Africa at least since the 11th century. It is still used to dye blue to blue-black cotton cloth, bark cloth (formerly), raffia and other vegetable fibres, leather, hair and wood carvings. This dyeing is still practised in many countries. It is very popular among the Baoulé dyers of central Côte d'Ivoire. In south-western Nigeria, Yoruba women use the plant, locally called 'elu', as their source of indigo dye in the art of making 'adire cloth', a decorative technique similar to batik (a method of dyeing a fabric by which the parts of the fabric not intended to be dyed are covered with removable wax), creating pale blue patterns on a dark blue ground. The dye is also very important in the cottage industry in Sierra Leone where 'gara cloth' is made. 'Gara' is the Madinka word for the traditional indigo dye found in many types of textiles of Sierra Leone. The source of this dye is the 'gara' leaf obtained from *Philenoptera cyanescens*. At present the word 'gara' is used both for the dyeing process (using both synthetic and natural dyes) and for the dyed products. It is believed that in the middle of the 19th century Susu and Madinka traders from Guinea, who came to settle in Kabala in the northern province of Sierra Leone, encouraged the native Temne women to develop gara dyeing. Traditionally woven cloth known as 'country cloth' dyed with gara was used by chiefs for ceremonial dresses, bridal dowry, burial clothes, court fines and gifts to important visitors. At present gara is worn by a much wider circle of people for aesthetic and cultural reasons. It is used for daily and ceremonial uniforms in some schools and offices. In the hotel industry gara is used widely as napkins, tablecloths, bedspreads, curtains and as backdrop for conference halls and lounges. *Philenoptera cyanescens* still plays an important role in gara dyeing.

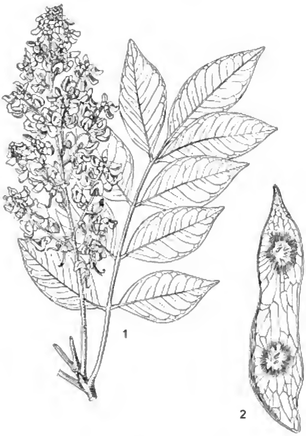
Leaves chewed with potash stain the teeth black. In Senegal the leaves are used as a condiment eaten with couscous. *Philenoptera cyanescens* is also used in traditional medicine. The leaves and roots are applied as a poultice or dressing to treat skin diseases and ulcers; in Ghana it is believed that the roots are more effective. In Sierra Leone and Guinea Bissau leaves and roots have been considered as a possible cure for leprosy. Leaves and bark are used as a laxative. In Benin leaf sap is drunk against intestinal disorders and dysentery. A decoction of leafy twigs and roots is given to women during or after childbirth and is also taken as an aphrodisiac. In Nigeria this decoction is used to treat arthritic conditions, venereal diseases and diarrhoea. Ground root is applied to yaws and washing with water containing powdered root helps to cure sores.

Production and international trade Formerly there was an export trade of dried *Philenoptera cyanescens* plant material to Europe, e.g. from Liberia. At present about 3000 people in Sierra Leone are engaged in gara production and trade and it has gained the status of a national identity symbol. Gara cloth, in addition to being used locally, is exported to the United States, United Kingdom and many African countries, but production statistics are not available.

Properties The leaves contain 0.1–0.3% of precursors of indoxyl and can yield an indigo dyestuff which contains up to 43% indigotin. During the dyeing process, in addition to indigotin and indirubin, a series of yellow flavonoid colorants such as quercetin, a quercetin glycoside, kaempferol and rhamnetin also become attached to the fibre, but they gradually disappear through wearing of the cloth, exposure to the sun and repeated washing. This loss of secondary compounds makes it difficult to determine which plant source has been used for the indigo dye in ancient African textiles: *Indigofera* or *Philenoptera*. In Ghana the fruits are believed to yield a better dye than the leaves. The anti-inflammatory activity of *Philenoptera cyanescens* has been confirmed by animal tests and is attributed to the presence of oleanane derivatives and glycyrrhetinic acid. A triterpene component of the plant has been found active against arthritis.

Adulterations and substitutes Several *Indigofera* spp. also yield indigo and are used similarly.

Description Deciduous scandent shrub up to 4 m tall (in cultivation usually up to 2.5 m) or liana up to 20 m long; bark grey to very pale brown, slash yellowish; branchlets silky when young. Leaves alternate, imparipinnately compound with 3–5 pairs of opposite leaflets, often drying bluish; stipules caducous; petiole 5–15 cm long, thickened at base; stipels filiform, early falling; petiolule 4–6 mm long; leaflets elliptical to ovate, 8–16 cm × 4–8 cm, base rounded to cuneate, apex usually pointed, margin entire, with 6–12 pairs of lateral veins, basal leaflets usually smaller than the other ones and the terminal leaflet largest. Inflorescence a terminal or axillary panicle up to 90 cm long, with short lateral branches. Flowers bisexual, papilionaceous; pedicel up to 2 mm long; calyx 3–4 mm long with pitcher-like tube and short teeth; corolla up to 1 cm long, white with blue markings to purplish or dark blue, glabrous, sweet scented; stamens 10, united into a tube; ovary superior, shortly stalked, 1-celled, style curved, stigma minute. Fruit a flat, more or less oblong pod 10–15 cm × 3–4 cm, pointed at both ends, with reticulate venation particularly prominent above seeds, long persisting on the plant, often drying bluish, 1–5-seeded. Seeds oblong to kidney-shaped, laterally flattened.



Philenoptera cyanescens – 1, part of flowering branch; 2, fruit.
Redrawn and adapted by Iskak Syamsudin

Other botanical information *Philenoptera* belongs to the tribe *Millettieae* and comprises 12 species confined to Africa and Madagascar. Formerly these species were grouped in *Lonchocarpus*, a genus now considered to be confined to tropical America, except *Lonchocarpus sericeus* (Poir.) Humb., Bonpl. & Kunth, which occurs in tropical America and Africa. *Lonchocarpus* differs in its inflorescences with flowers grouped in pairs or fascicles (singly in *Philenoptera*), hairy corolla and often truncate calyx.

Growth and development Flowering is at the beginning of the rainy season, more or less at the same time when new leaves appear.

Ecology *Philenoptera cyanescens* is found in coastal, riverine and fringing evergreen forest and thicket, and in wooded grassland and scrub vegetation, from sea-level up to 400 m altitude.

Harvesting Young, tender leafy twigs are collected whenever needed. It is believed that the best time for harvesting is just before flowering.

Handling after harvest Leaves and young shoots are bruised to a pulp and made up into balls about 10–12 cm in diameter, called 'arô' in Yoruba. These balls are dried in the sun and sold on markets. Sometimes only dry broken leaves and twigs are sold, not pulped into balls. The dye bath is prepared by soaking crushed balls in hot water, the number of balls depending on the desired intensity of the blue colour. Yoruba women in south-western Nigeria use from 50 balls for a bright blue up to 150 for a blue-black colour. The necessary alkalinity is obtained by adding lye from wood-ash. The solution is left to ferment for 6–8 days and the dye bath is then usually ready for the cloth to be steeped in it. The Wolof people in Senegal, who use a similar procedure, stimulate the fermentation process by adding some powdered root bark of *Morinda geminata* DC. ('vanda') which darkens the blue obtained and gives a reddish shine. A wide range of blue tones can be obtained depending on the number of dippings given to the cloth. In the Yoruba art of 'adire eleko', the cloth is patterned by applying a starch resist either free-hand with a comb or through a metal stencil. The starch paste used is made from the local glutinous cassava flour, always conveniently to hand as it is a common cooking ingredient. Then the cloth is folded gently and dipped into the indigo vat. It is kept still in it for about 3 minutes. Then the cloth is lifted out, hung up to drain and aired to help the indigo colour to develop on the cloth. It is usually folded again and dipped several times to produce pale blue patterns on a dark blue ground. Special patterns are reserved for ceremonial dresses of officials. In Sierra Leone two containers of 200 l are used to prepare an indigo vat, which is locally called 'setting the drum'. Gara leaves are put in the first drum and the second one is filled with the barks of the roots of *Morinda geminata* DC. and of the stems of *Jatropha curcas* L. and *Mangifera indica* L. The amount of *Morinda* root bark should be twice that of the other barks. The second drum is then filled with water, wood-ash lye or caustic soda is added, and the mixture is boiled for 6 hours. The resulting dark brown, hot liquid is poured on the gara leaves in the first drum and left to stand for 3 days. The resulting dye bath is dark green and ready for use. Nowadays, most dyers add some synthetic indigo at this stage and wait again until it is dissolved and reduced in the gara fermentation 'drum'. Dyeing itself is a multi-stage process, the number of stages depending on the techniques used for creating the design. If the design is waxed on to the fabric (using the batik technique) a cold dye bath is used. The fabric is first dipped into water before putting it into the dye bath to ensure an even colour. It is then left to soak (from 30 minutes up to 2 days) until the desired depth of colour is obtained. After being lifted out of the dye bath, the fabric is hung or spread out to dry to ensure complete oxidation, absorption and fixing of the dye. After drying, the fabric is washed with cold water several times until the water runs clear. It is then starched using cooked cassava starch and left to dry in the sun. When dried, the fabric is folded and beaten by a process known as calendering ('tapraka') to smoothen out all creases and give it a sheen and a permanent press finish.

Genetic resources *Philenoptera cyanescens* is widespread and not in danger of genetic erosion. In regions where it is much used and not cultivated it can become rare.

Breeding Higher yielding cultivars are relatively easy to obtain by mass selection because of available great differences, but no breeding programmes are known to exist.

Prospects *Philenoptera cyanescens* as source of the important gara dye in the cottage industry in Sierra Leone and as the indigo source in the 'adire' art of Yoruba in Nigeria is likely to gain more importance because of increasing popularity of the dyed products. Research for optimum cultivation methods and breeding of higher yielding cultivars is recommended.

Major references Balfour-Paul, 1998; Barbour & Simmonds, 1971; Burkill, 1995; Cardon, 2003; Polakoff, 1980; Schrire, 2000; Spencer, 1996.

Other references Berhaut, 1976; Hepper, 1958; Irvine, 1961; Jukema et al., 1991; Miège, 1992.

Sources of illustration Hepper, 1958.

Authors D. Cardon & P.C.M. Jansen

PHILENOPTERA LAXIFLORA (Guill. & Perr.) Roberty

Protologue Bull. Inst. Franç. Afr. Noire, Sér. A., 16(2): 354 (1954).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

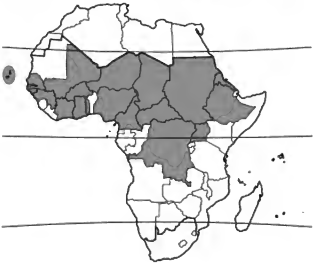
Chromosome number $2n = 22$

Synonyms *Lonchocarpus laxiflorus* Guill. & Perr. (1832), *Philenoptera schimperi* Hochst. ex A.Rich. (1847).

Vernacular names Gambian indigo (En). Savonnette (Fr).

Origin and geographic distribution *Philenoptera laxiflora* is widely distributed in tropical Africa from Cape Verde and Senegal to Eritrea and DR Congo.

Uses In West Africa, particularly in Senegal, Gambia and northern Nigeria, but also in the Kordofan province of western Sudan and in the Kasango region of eastern DR Congo, the leaves were and may still be used as source of an indigo dye in the same manner as those of gara (*Philenoptera cyanesceus* (Schumach. & Thonn.) Roberty) and the same range of blue colours can be obtained as with gara and Natal indigo (*Indigofera arrecta* Hochst. ex A.Rich.). In Gambia the dye was much used to make the famous 'bara siti' cloth in which decorative patterns are made by crumpling and binding parts of the tissue during the dye process. This tie and dye technique originates from the Soninké people in Senegal. In Senegal and Guinea, Tenda people use the bark in a condiment mixture. In the Central African Republic young leaves are eaten as a cooked vegetable and Gbaya people eat the flowers and fresh young fruits. The fruit is also eaten cooked with potherbs and sesame paste. After boiling, the fruits can be dried and stored for later use. The leaves are browsed or used as fodder for goats. In many places the tree is used for pole timber and as a source for fuelwood and charcoal. In Ghana, Senegal and Sudan the roots and bark are used as a tonic and to treat jaundice. In the Central African Republic a decoction of young leaves is taken against liver troubles. In Ethiopia the root is used externally against stomachache. In Nigeria and Sudan the leaves are applied as a poultice on ulcers and a decoction of the bark is used against intestinal problems of horses. In Nigeria leaves and bark are used as an insecticide and as an external anti-parasitic for scabies and ringworm. With its delicately scented blue or pinkish flowers, crowded in panicles all over the crown, *Philenoptera laxiflora* is a potential ornamental tree.

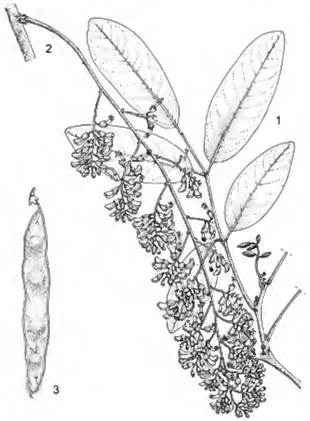


Philenoptera laxiflora – wild

Production and international trade Dyers in Gambia collect leaves from wild trees but also import *Philenoptera laxiflora* leaf balls from Sierra Leone and Nigeria. Production and trade statistics are not available.

Properties In Sudan (Kordofan) the dye obtained from *Philenoptera laxiflora* is considered of lower quality than the dye from *Philenoptera cyanescens*. The wood is pale yellow, hard and heavy. Research on the chemical composition of *Philenoptera laxiflora* is still needed, especially concerning the alleged presence of indigo precursors in the leaves. The isoflavanes lonchocarpane and laxiflorane and the pterocarpans philopterane and its 9-O-methyl derivative were isolated from the root bark.

Description Deciduous small tree up to 12 m tall; bark fibrous, grey or brownish outside, becoming rough and flaking, slash yellow-white exuding a red resin. Leaves alternate, up to 45 cm long, imparipinnately compound with 2–3 pairs of opposite leaflets; rachis of mature leaves 3–6 cm prolonged beyond upper pair of leaflets; stipules and stipels linear, up to 2 mm



Philenoptera laxiflora – 1, leafy branch; 2, inflorescence; 3, fruit.
Redrawn and adapted by Achmad Satiri Nurhaman

long, caducous; leaflets elliptical, 5–18 cm × 2–6 cm, terminal leaflet largest, slightly leathery, thinly hairy beneath, pinnately veined. Inflorescence a terminal or axillary panicle up to 60 cm long, at first erect but ultimately pendulous, strongly but shortly branched. Flowers bisexual, papilionaceous, up to 1.5 cm long; calyx campanulate, with short teeth; corolla pinkish-mauve to deep lilac with a median white or yellow patch inside on standard; stamens 10, united into a tube; ovary superior, shortly stalked, 1-celled, style curved, stigma minute. Fruit a narrowly elliptical to linear-oblong, flattened pod, 6–14 cm × 1–2 cm, narrowed at both ends, slightly sinuate between the 1–4 seeds, papery, shortly hairy and reddish green, becoming glabrous and pale brown at maturity. Seeds oblong to kidney-shaped.

Other botanical information *Philenoptera* belongs to the tribe *Millettieae* and comprises 12 species confined to Africa and Madagascar. Formerly these species were grouped in *Lonchocarpus*, a genus now considered to be confined to tropical America. When flowers and fruits are absent *Philenoptera laxiflora* can easily be confused with *Stereospermum kunthianum* Cham. (*Bignoniaceae*) in which however the leaf-rachis does not extend beyond the upper pair of leaflets.

Growth and development Flowering precedes or is simultaneous with the appearance of new leaves at the beginning of the rainy season.

Ecology *Philenoptera laxiflora* occurs in savanna or deciduous woodland, from sea-level up to about 2100 m altitude.

Harvesting Leaves can be collected whenever available in the rainy season.

Handling after harvest Leaves are bruised to a pulp and made up into balls 10–12 cm in diameter. These balls are dried in the sun and sold on markets. To dye cloth into various shades of blue, the dye-vat is prepared by soaking crushed balls in hot water, the number depending on the desired intensity of the blue colour. The necessary alkalinity is obtained by adding lye from wood-ash. The solution is left to ferment for 6–8 days usually and the dye bath is then ready for the cloth to be steeped into it. In the Kasongo region of DR Congo, young leaves of *Morinda lucida* Benth. are put into the dye-vat of *Philenoptera laxiflora* leaves and the resulting greenish dye is used to dye mats.

Genetic resources *Philenoptera laxiflora* is widespread and not in danger of genetic erosion. In regions where it is much used and not cultivated it can become rare.

Prospects As one of the sources of natural dyes for the important 'bara siti' cloth in the cottage industry in Gambia and as indigo source in various other countries *Philenoptera laxiflora* is only likely to retain some importance in regions where no better indigo sources of plant origin are available. Research on optimum cultivation methods for dye production and ornamental planting is recommended.

Major references Arbonnier, 2004; Burkill, 1995; Cardon, 2003; Gillett et al., 1971; Nacro & Millogo-Rasolodimbi, 1993; Schrire, 2000.

Other references Baumer, 1975; Berhaut, 1976; Hepper, 1958; Irvine, 1961; Pelter & Amenechi, 1969; Staner, 1936; Vergiat, 1970.

Sources of illustration Thulin, 1989.

Authors D. Cardon & P.C.M. Jansen

PHYLLANTHUS BOJERIANUS (Baill.) Müll.Arg.

Protologue DC., Prodr. 15(2): 343 (1866).

Family Euphorbiaceae (APG: Phyllanthaceae)

Origin and geographic distribution *Phyllanthus bojerianus* is endemic to Madagascar.

Uses The leaves or shoots of *Phyllanthus bojerianus* are used to colour fibres blackish, often with alum as a mordant. They are first bruised and then the mixture is boiled. When the decoction has become deep red, black mud is added, together with the fibres to be dyed. The mixture is regularly stirred and the fibres rubbed for a period of 12 hours. When the fibres have become black, they are dried. Another method is to boil a mixture of bruised leaves of *Phyllanthus bojerianus* and *Syzygium jambos* (L.) Alston. The fibres are first covered with black mud and added to the boiled mixture, in which they are left for 2 days. The fibres are then taken out, washed and dried.

Properties Although the chemical composition of *Phyllanthus bojerianus* has not been investigated, the reaction of the plant with black ferruginous mud tends to indicate that this species, like several other *Phyllanthus* spp., is quite rich in tannins.

Botany Dioecious, slender shrublet c. 1.5 m tall, stems sometimes climbing. Leaves alternate, simple and entire; stipules up to 1 mm long, persistent; petiole up to 1 mm long; blade narrowly elliptical-lanceolate but slightly curved, up to 6 mm × 2 mm, rounded at both ends. Inflorescence an axillary fascicle, 1–5-flowered. Flowers unisexual, regular, greenish white; pedicel up to 6 mm long; sepals 5–6, c. 1 mm long, persistent; petals absent; male flowers with 5 free stamens; female flowers with superior 3-lobed ovary crowned by 3 linear styles c. 1 mm long. Fruit a 3-lobed capsule c. 4 mm in diameter, up to 6-seeded.

Phyllanthus is a large genus comprising about 750 species in tropical and subtropical regions, with about 150 species in mainland tropical Africa and about 60 in Madagascar. Flowering and fruiting of *Phyllanthus bojerianus* is in November–December.

Ecology *Phyllanthus bojerianus* occurs in rocky localities up to 1600 m altitude.

Genetic resources and breeding *Phyllanthus bojerianus* is widespread in Madagascar and does not seem to be in danger of genetic erosion.

Prospects *Phyllanthus bojerianus* will remain of minor local importance only as a source of red or black dye. However, the use of natural dyes is being revived in Madagascar for raffia and for silk in the production of traditional textiles for the international market.

Major references Decary, 1946; Etheve, 2005.

Other references Leandri, 1958.

Authors P.C.M. Jansen

PHYLLANTHUS EMBLICA L.

Protologue Sp. pl. 2: 982 (1753).

Family Euphorbiaceae (APG: Phyllanthaceae)

Chromosome number $2n = 98, 104$

Synonyms *Emblica officinalis* Gaertn. (1790).

Vernacular names Emblic myrobalan, emblic, aonla, amla (En). Emblique officinale, bilimbi madras, myrobolan emblique (Fr). Mirabolano émblico (Po).

Origin and geographic distribution *Phyllanthus emblica* is indigenous to a large area ranging from Nepal, India and Sri Lanka, throughout South-East Asia to southern China. It is widely cultivated for its fruits throughout its natural area of distribution, particularly in India, and also in the Mascarene Islands (Réunion, Mauritius), the West Indies and Japan. Formerly it was cultivated in Madagascar.

Uses The leaves of *Phyllanthus emblica* are employed for dyeing matting, bamboo wickerwork, silk and wool into brown colours. Grey and black colours are obtained when iron salts are used as mordants. Matting can be dyed dark colours with a decoction of the bark. The fruits are used to prepare a black ink and a hair dye. Immature fruits, bark and leaves are used for tanning in India and Thailand, often in combination with other tanning materials such as chebulic myrobalan (*Terminalia chebula* Retz.) and beleric myrobalan (*Terminalia bellirica* (Gaertn.) Roxb.).

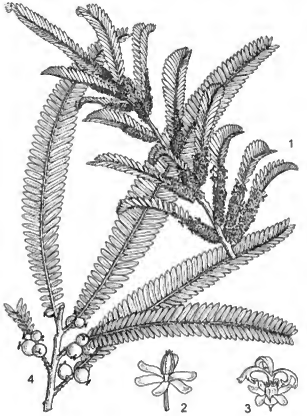
The fruits are edible but rarely eaten raw because they are astringent and sour. They are usually made into jam, jelly or syrup, or prepared in cooked food, or as sweetmeat and pickle. Leaves and fruits are used for animal fodder, whereas leaves can also be applied as green manure. Although the wood may warp and split, it is used for the construction of furniture and implements and it is very durable when submerged in water. The wood is also suitable as firewood and produces charcoal of good quality. All parts of *Phyllanthus emblica* are used medicinally with a vast range of applications. The plant is considered to have antiscorbutic, refreshing, diuretic, laxative and antibiotic properties and to be useful in the treatment of haemorrhages, diarrhoea, dysentery, anaemia, jaundice, dyspepsia, diabetes, fever, bronchitis and cough. A standardized extract of *Phyllanthus emblica* is traded in the United States as a component of anti-ageing, sunscreen and general-purpose skin care products.

Properties Fruits, bark and leaves of *Phyllanthus emblica* are rich in tannin. Dried pulp of unripe fruits contains 18–35% tannin; the content of ripe fruits is much lower. The dry stem bark contains 8–20% tannin. The bark of twigs is usually richer, containing 12–24% tannin on dry weight basis. Leaves may yield 22–28% tannin. The tannins of the fruit belong to the group of gallotannins and ellagitannins, giving on hydrolysis large amounts of gallic acid, small amounts of ellagic acid, and glucose. The tannin of the bark belongs to the group of proanthocyanidins, giving (+)leucodelphinidin on hydrolysis. *Phyllanthus emblica* tannin material gives a reddish brown leather with a soft grain, lacking somewhat in flexibility, which is why it is usually mixed with other tanning materials.

The fruit is an extremely rich source of ascorbic acid (vitamin C), 100 g of juice containing 600–1300 mg, sometimes even more. The tannin in the fruit prevents or retards the oxidation of the vitamin, so that the fruits can be preserved in salt solution or as dry powder while still maintaining their antiscorbutic value. The fruits have diuretic, laxative and purgative activities and also show molluscicidal and antimicrobial properties. They are a rich source of pectin. Fruits of wild plants weigh approximately 5.5 g, cultivated fruits average 28–50 g. Seeds yield about 16% of a brownish yellow oil with linoleic acid (44%), oleic acid (28.4%), linolenic acid (8.8%), stearic acid (2.2%), palmitic acid (3.0%) and myristic acid (1.0%). Seed weight is about 570 g per 1000 seeds. The wood is fairly heavy, weighing 720–930 kg/m^3 at 15% moisture content, and is hard and close-grained. It has a reddish colour and is liable to split.

Many of the medicinal applications of the fruits can be ascribed to the presence of ascorbic acid and to the astringent action of tannins, but the fruits contain other active compounds as well. Fruit extracts showed anti-oxidant and antitumour activities in in-vitro and animal tests. They also exhibited cholesterol-lowering, antitussive, anti-ulcerative and hepatoprotective properties and showed potent inhibitory activity on HIV reverse transcriptase; for the latter activity putranjivain A was the most active compound isolated. Phyllemblin has also been isolated from the fruits; it potentiates the action of adrenaline, has a mild depressant action on the central nervous system and has spasmolytic properties. *Phyllanthus emblica* leaf extracts have shown inhibitory activity on human leukocytes and platelets, which at least partly confirms the anti-inflammatory and antipyretic properties of *Phyllanthus emblica* leaves. The tannoid principles are potent inhibitors of aldose reductase and may be effective in the management of diabetic complications, including cataract.

Botany Small to medium-sized deciduous tree, sometimes up to 25 m tall but usually much shorter, up to 7.5 m; trunk often crooked and gnarled, up to 35 cm in diameter; bark thin, smooth, grey, peeling in patches, with numerous knobs. Leaves alternate, distichous and densely crowded along lateral twigs, simple and entire, glabrous, sessile; stipules triangular; blade narrowly oblong, 5–25 mm × 1–5 mm, rounded and more or less oblique at base, acute or obtuse and mucronate at apex. Flowers fascicled in axils of leaves or fallen leaves, unisexual, the male flowers numerous at base



Phyllanthus emblica – *1, flowering branch; 2, male flower; 3, female flower; 4, fruiting branch.*
Source: PROSEA

of young twigs, the female flowers solitary and higher up the twig; male flowers pedicellate, with 6 pale green perianth lobes 1.5–2.5 mm long and 3 entirely connate stamens; female flowers sessile, with 6 somewhat larger perianth lobes, a cup-like disk, and a superior 3-celled ovary crowned by 3 styles, connate for more than half of their length and deeply bifid at apex. Fruit a depressed globose drupe up to 4 cm in diameter, pale green changing to yellow when mature; stone with 3 slightly dehiscent compartments, each usually containing 2 seeds. Seeds trigonous, 4–5 mm × 2–3 mm.

Phyllanthus is a large genus comprising about 750 species in tropical and subtropical regions, with about 150 species in tropical Africa and about 60 in Madagascar. The feathery leafy and deciduous branchlets of several *Phyllanthus* spp. including *Phyllanthus emblica*, resemble pinnate leaves, for instance those of *Parkia* species.

Ecology In its natural distribution area *Phyllanthus emblica* is a light-demanding species, often common in grassy areas, brush and village groves. It is photosensitive, only producing flowers at a daylength between 12 and 13.5 hours. It occurs from almost sea-level up to 1500 m altitude. The tree is slightly tolerant of alkaline soils and rather drought resistant, but some cultivars are sensitive to drought and frost. It is fire-resistant and is one of the first trees to recover after a fire. The tree is rather slow-growing. It usually starts bearing fruits when at least 8 years old, but sometimes trees start producing fruits when 5–6 years old. In many areas, full-grown trees are rare as a result of slow growth and exploitation.

Management In the past, propagation of *Phyllanthus emblica* was usually by seed. For extensive production and selection, vegetative propagation is necessary. A high percentage of rooting (84%) has been reported from semi-hard wood cuttings collected from the middle portions of vigorous shoots of young trees and planted in beds at a temperature of about 33°C. Budding and softwood grafting may also give good results. In the early stages of growth, copious watering in the dry season and weeding are necessary. The tree coppices well and pollards moderately well. Coppiced shoots grow particularly vigorously, and coppicing is considered the system most suitable for the production and collection of tanbark on a commercial scale. Usually plantations need much weeding because the thin crowns do not form a closed canopy. A dieback disease is caused by *Botryodiplodia theobromae*, and seedlings are susceptible to a root-rot disease caused by *Rhizoctonia solani*. Trees may be affected by rusts such as a leaf rust caused by *Phakopsora phyllanthi* and a ring rust caused by *Ravenelia emblicae*. Bark-eating caterpillars (*Indarbela* spp.) damage trees. The fruits are susceptible to rot diseases as a result of infection by *Penicillium* spp., *Glomerella cingulata*, *Phoma putaminum* and *Aspergillus niger*.

The fruiting season is exceptionally long since the ripe fruits may be retained for several months on the tree without significant loss of quality. Because of this, a long period is available for picking the fruits for consumption. The average annual yield of wild trees in India is about 15 kg of fruit per tree. Some cultivars may yield over 25 kg. Fresh fruits are not palatable because of their astringent and sour taste. The astringency can be removed by steeping the fruits in brine for a few days. Fruits are often preserved by splitting, removing the stone, putting the segments into a solution of 42% glycerol, 42% sucrose, water and preservatives, then heating to 90°C for 3 minutes. The fruits are allowed to equilibrate in the solution for two days at 2°C, then they are drained and packed into containers. Fruits preserved in this way remain acceptable for about 2 months at room temperature, and much longer when cooled, but the ascorbic acid content drops slowly. Marketability of fresh fruits is improved by a combined treatment with wax emulsion and 10 mg/l morphactin. This delays browning and reduces the infection rate from *Aspergillus* and *Penicillium* species. For medicinal purposes, fruits are simply dried. For use in tanning, the fruits should be harvested unripe. The stone of unripe fruits should be removed and the remaining flesh dried and ground to prepare a tanning material.

The bark of shoots less than 5 cm in diameter is used to obtain a good tannin. Usually branches can be coppiced every 2 years. Quickly-dried bark contains much more tannin than slowly-dried bark. Therefore it has been recommended to dry the bark rapidly in the sun.

Genetic resources and breeding *Phyllanthus emblica* is widespread and does not seem to be in danger of genetic erosion. In India fruit tree cultivars have been developed, e.g. 'Banarasi', 'Chakla', 'Desi', 'Francis', 'Kanchan' and 'Krishna'.

Prospects *Phyllanthus emblica* deserves more attention and is possibly also of interest for tropical Africa. It has interesting aspects as a tannin and dye-yielding species because it could be a regular supplier of tanning and dyeing material by coppicing the tree or harvesting young fruits. Trees are not killed at harvest as is so often the case with species yielding tanbark. *Phyllanthus emblica* is not easy to cultivate on a large scale. It is rather slow-growing and needs much weeding. New experiments to discover better methods of cultivation might be worthwhile. Selection for large edible fruits is normally not compatible with selection for fruits with high tannin content, but combined selection for tanning and medicinal purposes seems to be possible. *Phyllanthus emblica* has great therapeutic potential.

Major references Calixto et al., 1998; van Holthoon, 1999; van Schaik-van Banning, 1991.

Other references Gurib-Fakim, Guého & Bissoondoyal, 1996; Leandri, 1958; Rajak et al., 2004; Suryanarayana et al., 2004.

Sources of illustration van Schaik-van Banning, 1991.

Authors P.C.M. Jansen

Based on PROSEA 3: Dye and tannin-producing plants and PROSEA 12(1): Medicinal and poisonous plants 1.

PSILANTHUS EBRACTIOLATUS Hiern

Protologue Oliv., Fl. trop. Afr. 3: 186 (1877).

Family Rubiaceae

Chromosome number $2n = 22$

Synonyms *Coffea ebractiolata* (Hiern) Brenan (1953).

Origin and geographic distribution *Psilanthus ebractiolatus* is distributed from Guinea to Cameroon.

Uses Ground fruits and seeds of *Psilanthus ebractiolatus* are used in Ghana to make black tattoos. Toothbrushes are made from the wood. Roasted fruits smell distinctly of coffee and are used as a substitute. In Côte d'Ivoire the leaves are used medicinally against Guinea worm. A soft paste made from the leaves, with garlic and lemon, is applied to the puncture marks on the skin caused by the worms, which after a few days are killed and can be gradually removed.

Botany Shrub or small tree up to 5 m tall, with slender branches, glabrous. Leaves opposite, simple and entire; stipules small, connate or sheathing; petiole up to 2 mm long; blade elliptical, up to 10 cm × 5 cm, base cuneate, apex acuminate, glossy, lateral veins in 3–4 pairs, looping. Flowers solitary, terminal, bisexual, regular, 5-merous, c. 2.5 cm long, fragrant during the night, sessile; calyx shallowly cup-shaped, truncate; corolla white, tubular, tube slightly longer than lobes; stamens with short filaments, anthers completely included in corolla tube; ovary inferior, 2-celled, style 2-fid, remaining within corolla tube. Fruit an obovoid to ellipsoid drupe c. 12 mm in diameter, distinctly 2-lobed, containing 2 leathery, 1-seeded pyrenes, black when dry. Seeds grooved on inner surface, smooth.

Psilanthus comprises about 20 species, confined to the Old World tropics. The taxonomic position of *Psilanthus* has not yet been firmly established; it is sometimes considered to be part of *Coffea*, from which it differs by its corolla tube, which is longer than the lobes and by its anthers and style, which are not exserted.

Ecology *Psilanthus ebractiolatus* is found in closed forest, in humid as well as semi-dry forest, at low altitudes.

Genetic resources and breeding *Psilanthus ebractiolatus* is widespread and does not seem to be in danger of genetic erosion. For purposes of coffee breeding, in hybridization experiments using tetraploidized accessions of *Psilanthus ebractiolatus* some fertile hybrids were obtained in crosses with *Coffea arabica* L. ($2n = 44$).

Prospects *Psilanthus ebractiolatus* as source of a dye will remain only very locally of some importance. Its medicinal properties need further investigation. Its successful hybridization with *Coffea arabica* opens up new prospects in coffee breeding.

Major references Abbiw, 1990; Burkill, 1997; Irvine, 1961.

Other references Bridson, 1987; Couturon, Lashermes & Charrier, 1998; Hepper & Keay, 1963; Hiern, 1877; Kerharo & Bouquet, 1950.

Authors P.C.M. Jansen

PSYCHOTRIA PSYCHOTRIOIDES (DC.) Roberty

Protologue Bull. Inst. Franç. Afrique Noire, ser. A, 16: 62 (1954).

Family Rubiaceae

Synonyms *Grumilea psychotrioides* DC. (1830).

Vernacular names Azier, café marron (Fr).

Origin and geographic distribution *Psychotria psychotrioides* is distributed from Senegal east to Sudan, and south to Gabon and DR

Congo.

Uses The bark of *Psychotria psychotrioides* yields a red dye which is used to dye textiles, e.g. in Sierra Leone. In Senegal early symptoms of eye troubles are treated with a decoction of the bark in a steam bath, whereby a sheet covers the head of the patient and the container with the steaming liquid. To combat headache and depressions a leaf maceration is rubbed on the forehead or the sap is drunk. The root or whole plant yields a widely used expectorant medicine for asthma and bronchitis.

Properties The chemical nature of the red dye has not been studied. Whatever the chemical composition of the red dye is, the dye potential of *Psychotria psychotrioides* is optimized by the mordanting effect of the high concentration aluminium present in the leaves. Aluminium accumulation in leaves seems to be a chemotaxonomic characteristic of *Psychotria*. Aluminium salts are the main mordants used to strengthen and multiply the chemical bonds between textile fibres and most natural dyes.

Botany Shrub up to 6 m tall, with rounded, glabrous branches; bark pale brown, c. 3 mm thick. Leaves opposite, simple and entire, glabrous; stipules oblong-ovate, 7–15 mm long, not persistent; petiole 1–6 cm long; blade elliptical, ovate, obovate or linear, 5–30 cm × 1–15 cm, base rounded to cuneate, apex acute to rounded, lateral veins in 5–12 pairs. Inflorescence a sessile head 1–1.5 cm in diameter, densely clustered, subtended by 2 circular, deciduous bracts c. 1 cm in diameter. Flowers bisexual, regular, 5–6-merous, heterostylous, sweet smelling, sessile; calyx campanulate, 3–5 mm long, irregularly incised; corolla tubular, tube 6–10 mm long, lobes up to 3 mm long, white; stamens in long-styled flowers up to 1 mm long, in short-styled ones up to 3 mm; disk rounded; ovary inferior, 2-celled, glabrous, style up to 5 mm long in short-styled flowers, up to 8 mm in long-styled ones, stigmas 2, up to 1.5 mm long. Fruit a globose to ellipsoid drupe, 8–13 mm × 6–9 mm, red, strongly ribbed, with persistent calyx at apex, containing 2 pyrenes.

Psychotria is a very large and insufficiently known genus comprising about 500 species distributed pantropically. About 200 species are present in tropical Africa. The genus is classified in subfamily *Rubioideae*, tribe *Psychotrieae* and it is subdivided in various subgenera and sections, but this classification has not yet stabilized. *Psychotria psychotrioides* is easily recognized by its sessile head-like inflorescences subtended by large bracts when young; the leaves are very variable.

In the literature the following African *Psychotria* species have also been reported as yielding a red dye in the bark and sometimes also leaves, which is used to dye textiles:

- *Psychotria bidentata* (Thunb. ex Roem. & Schult.) Hiern: shrub up to 6 m tall; leaves elliptical, 7–19 cm × 2–8 cm; inflorescence head-like, peduncle up to 11 cm long; flowers white, 5-merous, heterostylous; calyx tube less than 1.5 mm long, lobes less than 1 mm long. It occurs in forests from Senegal to Benin. In Sierra Leone a root decoction is given to babies with stomach-ache.
- *Psychotria reptans* Benth. (synonym: *Psychotria strictistipula* Schnell): small shrub up to 60 cm tall; leaves elliptical, 5–16 cm × 1.5–6 cm; inflorescence paniculate, peduncle up to 6 cm long; flowers white, 5-merous; calyx tube 1–1.5 mm long, lobes shorter; fruits white. It occurs in forests from Guinea to Ghana.
- *Psychotria rufipilis* De Wild.: shrub up to 1.5 m tall; leaves obovate to elliptical, 4–20 cm × 1.5–8 cm, veins hairy; inflorescence paniculate or head-like, peduncle up to 5 cm long; flowers white, sessile or pedicellate, 5-merous, heterostylous; calyx tube 1.5–2 mm long, lobes 1–2 mm long. It occurs in savanna and gallery forest from Guinea to Côte d'Ivoire. In Liberia an astringent drink or liquor is made from the bark (sometimes leaves added) and given to children with peeling skin and diarrhoea.

Ecology *Psychotria psychotrioides* is found in closed and fringing forest and in savanna woodland, from sea-level up to 1200 m altitude.

Genetic resources and breeding *Psychotria psychotrioides* is very widespread and common in Africa and is not in danger of genetic erosion.

Prospects As sources of a red dye, the bark and leaves of *Psychotria psychotrioides* and several other *Psychotria* species may remain of minor importance locally but with the present emergence of worldwide interest in natural dyes as renewable sources of non-polluting colorants, the combination in the same plant of a red dye and a mordant makes *Psychotria psychotrioides* a potentially interesting source of red colorants. Its chemical composition and medicinal properties need further research.

Major references Burkill, 1997; Petit, 1964.

Other references Hepper & Keay, 1963; Hiern, 1877; Irvine, 1961; Jansen et al., 2000; Kerharo & Adam, 1974; Neuwinger, 2000; PharmaPro, 1997–2002.

Authors P.C.M. Jansen

PTEROCARPUS ANGOLENSIS DC.

Protologue Prodr. 2: 419 (1825).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Synonyms *Pterocarpus bussei* Harms (1902).

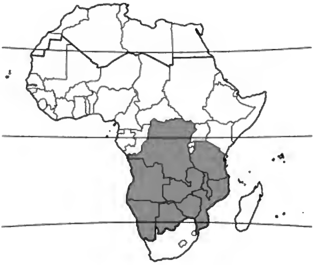
Vernacular names African bloodwood, mukwa, kiaat, muninga (En). Ambila, umbila, njila sonde (Po). Mninga, mdamudamu, mtumbati (Sw).

Origin and geographic distribution *Pterocarpus angolensis* is widespread in southern tropical Africa, from Angola, DR Congo and Tanzania south to north-eastern South Africa and Swaziland. It has been planted on a small scale in Kenya.

Uses In southern Africa *Pterocarpus angolensis* is one of the most generally used and most valuable timber trees. The wood is used for construction, carpentry, furniture manufacture (tables, chairs, benches), parquet flooring and veneer, and in South Africa and Namibia particularly for wood carving (bowls, spoons and walking sticks). Due to its flexibility, resistance and light weight it is also useful for boats, doors and windows. It is occasionally used for firewood.

The heartwood of the roots, pounded to powder, yields a fast brownish red dye which is used in the cottage industry in Namibia and Zimbabwe, mainly to dye palm-leaf fibres for basket weaving. The powder is also mixed with oil or fat to make a cosmetic pomade, which had great cultural importance and still has to a lesser extent in Namibia (Ovambo people), Zambia (Ndembu people) and Angola. It is traditionally applied to all exposed portions of the body, including hair, face, breasts, arms and legs. It is also used to dye leather clothing (skirts or aprons of cowhide or tanned cow stomach), which is the traditional form of clothing for men and women alike and it still has cosmetic, medicinal and symbolic importance. The inner bark and heartwood of the trunk and branches are also said to be used by some people to obtain dye.

The inner bark is fibrous and is used in basketry. In traditional medicine the bark with its blood-red, gummy, resinous exudate ('false dragon's blood' or 'kino') is used as a powerful astringent, e.g. to treat diarrhoea, heavy menstruation, nose bleeding, headache, stomach-ache, schistosomiasis, sores and skin problems. The root is believed to cure malaria, blackwater fever and gonorrhoea. The seed ash is applied as a dressing on wounds and psoriasis in South Africa. Leafy twigs are used as fodder and flowering trees are an important source of honey. *Pterocarpus angolensis* is nitrogen fixing and planted for soil conservation, dune fixation, live fencing and as an ornamental casting a light shade and with attractive fruits. The bark has been used as fish poison.



Pterocarpus angolensis – wild

Production and international trade In southern Africa *Pterocarpus angolensis* is the most widely used timber tree. Production and demand are huge although statistics are hardly available. In 1996 about 5500 m^3 was exported from Cabo Delgado Province in Mozambique, and the annual export from Zambia is at least 5000 m^3. Most of the timber is exported to China and Thailand. The export price of superior quality sawn *Pterocarpus angolensis* wood from Zambia is US$ 575/m^3. At the beginning of the 1990s, the annual export of timber from South Africa was estimated at US$ 650,000; at present it may fetch prices of over US$ 700/m^3. The price of one kg of wood used for carving in South Africa is US$ 1, but after carving it averages US$ 7.

Bark, chips and sawdust for dye production are available in considerable amounts as by-products of the timber. In rural areas many families largely depend on the income generated from the small-scale woodcraft, furniture and basketry industries, which thus support the poorest sectors of communities. In some regions, e.g. north-eastern South Africa, tableware and utensils made of *Pterocarpus angolensis* wood are common items in tourist markets and shops.

Properties *Pterocarpus angolensis* wood is a relatively light hardwood. The heartwood is pale to dark brown or reddish brown, often with streaks, and distinctly demarcated from the pale grey or pale yellow sapwood. In Tanzania it was estimated that the percentage of heartwood is about 70% for a bole of 30 cm in diameter and about 80% for one of 50 cm in diameter. The density is 400–700 kg/m³ at 12% moisture content. The grain is straight to interlocked, texture medium to coarse. At 12% moisture content, the modulus of rupture is 94 N/mm², modulus of elasticity 8400 N/mm², compression parallel to grain 57 N/mm², Janka side hardness 6585 N and Janka end hardness 5380 N.

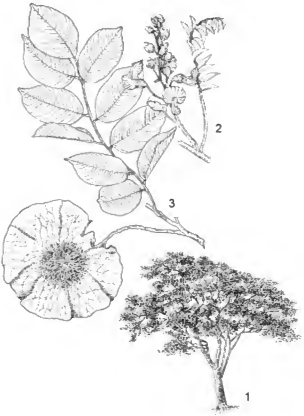
The shrinkage rates of the wood are low, from green to 12% moisture content 1.0% radial and 1.5–1.6% tangential. The wood dries well but slowly, without warping and with little or no tendency to check or split. It takes 50–90 days to air dry 25 mm thick boards from 70% to 12% moisture content, and 15–20 days by kiln drying. Once dry, it is very stable. It works well with hand and machine tools, only moderately blunting cutters; straight-grained material planes and finishes well. The bending properties are moderate. The wood is easy to peel and slice, and has good gluing and excellent turning and carving properties. The dry sawdust may cause irritation to nose and bronchia. The heartwood is moderately durable; it is moderately resistant to termites and marine borers. The sapwood is liable to powder-post beetle attack. The heartwood is resistant to preservative treatment, the sapwood moderately resistant. A defect reported frequently is a mottling of the timber with irregular white spots up to 5 mm in width, caused by an organic component which accumulates locally. The spots penetrate deeply into the wood and are obvious especially in veneers.

Recent analyses of samples of *Pterocarpus angolensis* heartwood have failed to detect any of the red biflavonoids such as santalins and santarubins, which are characteristic of commercial 'insoluble redwoods' from other *Pterocarpus* species. However, isoflavonoids are present, including prunetin, muningin, tectorigenin 7-methylether, pseudobaptigenin and angolensin, accounting for the brownish colour of the dye, but elucidation of the exact dye composition needs further research. The dried exudate collected from the bark contains about 75% tannin, mainly composed of kinotannic acid.

Root extracts are lethal to adult schistosomes causing bilharzia and are comparable to praziquantel, an efficacious antischistosomal drug.

Adulterations and substitutes The wood of *Pterocarpus angolensis*, which is popular because of its streaked appearance and superior carving properties, is replaced in regions where it has become scarce by that of other indigenous species and occasionally of planted exotic species. However, there are a few alternatives, e.g. *Afzelia quanzensis* Welw. and *Brachylaena huillensis* O.Hoffm., which are commonly used for carving in Zimbabwe and Kenya, respectively, and the planted *Azadirachta indica* A.Juss.

Description Deciduous medium-sized tree up to 25(–35) m tall; bole straight, up to 50(–100) cm in diameter; bark c. 1.5 cm thick, rough and cracked into more or less rectangular blocks when old, grey to brown, exuding a red resinous sap on slashing; crown open, spreading, flat; twigs thinly to densely brown or silver-grey hairy, gradually becoming glabrous. Leaves alternate, imparipinnately compound with (9–)11–25 leaflets, drooping; stipules lanceolate to elliptical, up to 2 cm long, falling off early; petiole 2–8 cm long, rachis 11–



Pterocarpus angolensis – 1, tree habit; 2, part of flowering twig; 3, fruiting twig.
Redrawn and adapted by Iskak Syamsudin

35 cm long, densely hairy; leaflets alternate to nearly opposite, broadly lanceolate to elliptical-oblong or elliptical-obovate, 3.5–10 cm × 2.5–5.5 cm, base rounded to slightly cordate, apex acuminate, hairy on both sides when young, with 10–14 pairs of fine lateral veins. Inflorescence an axillary raceme 6–12 cm long, often developing before the new leaves, densely hairy; bracts elliptical-oblong, up to 9 mm long, caducous. Flowers bisexual, papilionaceous, fragrant; pedicel 5–20 mm long, densely hairy; calyx campanulate, c. 1 cm long, shortly 5-lobed with 2 upper lobes connate; corolla up to 2 cm long, golden-yellow to orange, standard almost circular with crimped margin and claw, wings broad, nearly as long as the standard, clawed, keel smaller, clawed; stamens 10, connate but sometimes 1 stamen partly or completely free; ovary superior, 1-celled, stalked, hairy, style slightly curved, stigma terminal, small. Fruit an almost circular indehiscent pod (6–)9–12(–16) cm in diameter, c. 2.5 cm thick, on a stalk up to 2.5 cm long and with an up to 3 cm broad undulate almost circular wing, pubescent and with a mass of plumose bristles up to 13 mm long over the central thickened part, green at first, yellow-brown when mature, 1(–2)-seeded. Seed asymmetrical, 10–20 mm × 7–8 mm × 4–5 mm, smooth, red-brown, hard. Seedling with epigeal germination.

Other botanical information *Pterocarpus* is a pantropical genus belonging to the tribe *Dalbergieae*, comprising 21 species of which 12 occur in Africa, 6 in America and 5 in Asia. Several Asiatic and African species were important commercial sources of red dyes, but most species are now much more valuable for timber.

Anatomy Wood-anatomical description:

- Macroscopic characters:
  Heartwood pale to dark brown or reddish brown, often with streaks, distinctly demarcated from the pale grey or pale yellow sapwood. Grain straight to interlocked. Texture medium to coarse.
- Microscopic characters:
  Growth rings usually distinct. Vessels diffuse, 1–2/mm², in radial multiples of 2–3, mean tangential diameter 115–300 µm; perforations simple; intervessel pits alternate, 8–13 µm in diameter, vestured; vessel-ray pits similar to intervessel pits, but sometimes with apparently simple borders; helical thickenings absent, orange-brown deposits in heartwood vessels present. Fibres 1050–1650 µm long, non-septate, medium-thick walled. Axial parenchyma banded, apotracheal and paratracheal; apotracheal parenchyma diffuse-in-aggregates, paratracheal parenchyma aliform and confluent. Rays 12–17/mm, multiseriate, 1–2 cells wide, up to 500 µm high, homocellular, with procumbent cells. Prismatic crystals present in chambered axial parenchyma cells. Vessel elements, fibres, axial parenchyma strands and rays distinctly storied.

Growth and development Although *Pterocarpus angolensis* can produce ample seed (up to 10,000 fruits/ha are recorded), germination is poor. Under natural conditions only 2% of the seed germinates and half of the seedlings produced die in the first year. After germination the seedling rapidly develops several shoots and a strong taproot, which may reach to a depth of 1 m in the first year. The shoots reach about 15 cm length in the first year and often die back in the dry season. The plants enter a suffrutex stage, in which the root expands in size and lateral roots develop in the top 50 cm of the soil, while shoots usually die back to below ground level in the dry season. New shoots develop in the rainy season. This stage may last for 10 years (sometimes up to 25 years) until the root has sufficiently developed to allow the above-ground part of the sapling to survive the dry season. Many seedlings do not survive the suffrutex stage because of drought, burning, nutrient deficiencies (particularly boron) and damage by browsing animals. Initial shoot growth of saplings forms a zigzag pattern because of the yearly dieback of the top 10 cm. After the suffrutex stage, the growth is fast, up to over 2 m in one year, and the tree rapidly reaches a height where it cannot be reached by most browsing animals. Compared to other trees the saplings with a thick corky bark are extremely fire resistant, sometimes surviving temperatures of up to 450°C, and fires contribute to pruning side branches and multiple stems. During the first decade following the suffrutex stage, height rather than diameter increases, while in the 2nd decade the diameter increases more rapidly. Trees start flowering when they have a permanent stem of 15–20 years old, but full development of fruits usually only starts when trees are about 35 years old. The ripe fruit weighs 5–10 g, but because of the large wing wind transport is possible, usually up to 30 m from the mother tree. The spiny centre of the fruit also favours dispersal by animals. The phenology is tightly synchronized with the seasonality of the rainfall and flowering starts at the beginning of the rainy season. In general flowering and leaf flush occur from (August–) September to November (–December), fruits ripen from January to April and may remain on the tree until far into the next flowering season, leaves are shed in May–June. Flowering is short, usually only 2–3 weeks, and pollination is by insects (e.g. honey bees). Fruit development takes about 4–5 months. Trees growing on good sites in full light live for up to 100 years, by which age they are about 20 m tall, with a crown diameter of 10–12 m and a bole diameter of 50–60 cm; bark thickness is 1.5–2 cm and sapwood 5 cm thick. Bole length will depend largely on the life history of the tree, but is favoured if the stand has been burned since the tree was about 5 years old and if pruning is carried out. The annual diameter increment of the bole was estimated 5.5–8.5 mm in Tanzania. In Mozambique it was estimated that a tree of 50 cm in bole diameter has a mean timber volume of 1.9 m^3 and 5.3 m^3 for 80 cm diameter.

Ecology *Pterocarpus angolensis* is typically found in so-called miombo woodland with *Brachystegia* and other deciduous trees, in wooded grassland and savanna, from sea-level up to 1650(–1800) m altitude. It requires well-drained, medium to light soils of low to moderate fertility and pH 5.5–7. In Tanzania it occurs preferentially in moister localities in wooded grassland of the coastal plains. It prefers a climate with well-defined wet and dry seasons, with an average annual rainfall of 500–1500 mm and average temperatures of 15–32°C. It is not resistant to frost, although older trees survive very light frosts. It is a pioneer species in disturbed and open sites, requiring full sun. Rainfall is more important than a permanent subterranean water supply and under conditions of exceptional competition for ephemeral water resources the tree does not survive.

Propagation and planting *Pterocarpus angolensis* can be propagated by seed and by cuttings. A tree produces on average annually 100–400 fruits and there are 3400–4000(–5000) seeds per kg. At moisture contents of 4–6% seeds can be stored cold for at least 3 years. Collection of seed for the purpose of raising plants in a nursery is difficult because it is difficult to open the pods without damaging the seed and because many pods are empty (about 50% of young seed aborts). Pods can be opened manually with secateurs, which is however time consuming. Damaged seed usually fails to germinate, but mycorrhizal associations also influence germination. Yearly dieback, a long suffrutex stage and damage to the root system when transplanting are other nursery problems that are difficult to solve. Therefore, it is easier to start *Pterocarpus angolensis* plantations at natural sites where plants in the suffrutex stage are already present and fill in gaps by planting suffrutex plants collected from nearby vegetation. These should be taken with as large a taproot as is possible while lateral roots can be lightly trimmed. Light is very important for good growth, so planting distance of trees should at least be 5 m × 5 m, but ultimately the number of trees will be 25–100/ha, largely depending on crown and root competition. Cuttings (e.g. 2 m long and at least 2 cm in diameter) can be planted at the beginning of the rainy season but success rates vary from 0–30%. Planting of truncheons 10 cm in diameter into 1 m deep plant holes with some coarse river sand at the bottom has also been recommended.

Management Once trees are established not much care is needed. Management can be restricted to taking care that each individual tree gets enough light. Protection against damage by wild animals and bush fires can enhance growth, although *Pterocarpus angolensis* is one of the most fire-resistant trees of miombo woodland. In western Tanzania recruitment of new trees in selectively logged areas was found to be poor. The density of *Pterocarpus angolensis* was higher near the main road than at some distance, which may be explained by reduced damage by wild grazers and lighter bush fires in the more open vegetation near the road. After felling most trees do not resprout from the stump because they have a poor coppicing ability. In practice rotation periods vary from 40–75 years.

Diseases and pests Periodically, *Pterocarpus angolensis* tree populations suffer from 'mukwa' dieback, a badly understood tree-killing fungal disease which blocks up the xylem. In Zambia, for example, an outbreak of the disease killed 40% of the trees. Fire damage can result in fungal (e.g. *Armillaria mellea*) and borer attack of the heartwood. A large number of wild animals can cause damage to *Pterocarpus angolensis* by browsing, bark stripping, stem breaking by rubbing or uprooting. Elephants particularly are destructive, and wild pigs are fond of suffrutex roots. Seeds are often attacked by bruchid beetles.

Harvesting In South Africa trees should have a minimum diameter of 27 cm to be considered harvestable as timber. Growing time to reach this diameter differs per region; in South Africa it takes on average about 80 years, in Zambia and Tanzania possibly 40–75 years. The minimum cutting diameter in Tanzania and Zimbabwe is 25 cm.

The kino resin from the bark can be harvested by making incisions in the bark and collecting the exuding sap. Roots are dug up to extract the dye. For extracting the dye from the heartwood adult trees should be felled, but this is normally only done for use as timber.

Yield Timber yield data are not available and vary largely from site to site. In Namibia for certain areas annual allowable cut was estimated at 600 m^3 per 100 km^2. In the miombo woodland of Tanzania, the sustained annual yield of commercial timber of *Pterocarpus angolensis* was estimated at 0.33 m^3 per km^2. On average, recovery from roundwood to sawn wood is about 40%.

Handling after harvest Usually trees are hand cut, the logs rolled to saw pits and sawn into boards, which are brought by trucks to train depots. For preparing the dye and cosmetic pomade, the heartwood of roots is ground to a powder or paste or chipped very finely. To make the cosmetic, it is mixed with butter or vegetable oil from pounded seeds (e.g. of *Schinziophyton rautanenii* (Schinz) Radcl.-Sm., *Ricinus communis* L., *Sclerocarya birrea* (A.Rich.) Hochst., *Ximenia caffra* Sond.) and it is often perfumed by adding dried and ground *Ocimum* leaves.

In Zimbabwe strips of palm leaves are boiled for about 12 hours in a dye bath containing hot water and *Pterocarpus angolensis* bark. After drying, the resulting red-brown fibres are used to obtain coloured designs in basketry weaving. The dye obtained by extracting finely chopped roots or wood in alcohol can be used to dye wool and cotton various shades of brown to bright red.

Genetic resources Although *Pterocarpus angolensis* is widespread in many parts of southern Africa, overexploitation endangers many populations. It is classified by IUCN in the category 'lower risk', but is close to qualifying for vulnerable. In South Africa the tree has been protected since 1967 and a special permit is needed for cutting. In Tanzania little infraspecific variability has been discovered in *Pterocarpus angolensis*.

Prospects *Pterocarpus angolensis* is a very useful multipurpose tree in southern Africa, producing multipurpose timber, dye, forage and medicine. Overexploitation endangers natural populations in all countries and the current harvest for timber is unsustainable, raising serious concerns about the long-term viability of this important hardwood species. Research for large-scale cultivation is needed, especially to improve the germination rate of seed, shorten the suffrutex stage of plants and accelerate growth of young trees. Sustainable management systems should be developed for miombo woodland in which *Pterocarpus angolensis* has an important share. The dye composition of the heartwood of this species needs further research. More research is also needed to determine whether more profit can be made from the chips, sawdust and bark as by-products of timber exploitation, e.g. for the production of dye and medicinal products.

Major references Boaler, 1966; Cardon, 2003; Coates Palgrave, 1983; Gillett et al., 1971; Gomes e Sousa, 1951; Graz, 2004; International Centre for Research in Agroforestry (ICRAF), undated a; Rojo, 1972; Schwartz, Caro & Banda-Sakala, 2002; Surowiec, Nowik & Trajanowicz, 2004.

Other references Botha, 2005; Bryant, 1968; Chakabva & Mushove, 1993; Chudnoff, 1980; Joker, Msanga & Schmidt, 2000; Palmer & Pitman, 1972–1974; Richter & Dallwitz, 2000b; Rodin, 1985; Rojo & Alonzo, 1993; Schwartz & Caro, 2003; Swart & Vermeulen, 1984; van Wyk, 1972–1974.

Sources of illustration Coates Palgrave, 1957; Gillett et al., 1971.

Authors R. Takawira-Nyenya

PTEROCARPUS SOYAUXII Taub.

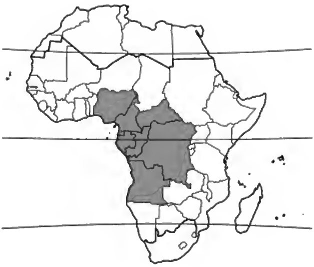
Protologue Oliv., Hooker's Icon. pl. 24: t. 2369 (1895).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Vernacular names African padauk, African padouk, barwood, African coral wood (En). Padouk d'Afrique, padauk d'Afrique, bois corail (Fr). Ndimbu, nkula (Po).

Origin and geographic distribution *Pterocarpus soyauxii* occurs from south-eastern Nigeria east to eastern DR Congo and south to northern Angola.

Uses The wood of *Pterocarpus soyauxii* is a valuable multipurpose hardwood. Because of its resistance to water it is locally used to make canoes and because of its beautiful reddish colour it is favoured for carving and sculptur-



Pterocarpus soyauxii – wild

ing, furniture, cabinets, knife and tool handles, traditional hair combs, walking sticks and musical instruments. The wood has a high resonance quality as its damping of vibrations is low and formerly large telegraph slit drums and war drums, as well as xylophones, were made from it in DR Congo and Gabon. It is currently used also for 'Western music' xylophones and increasingly tried for the back and sides of guitars. Because of its high durability the wood is excellent for construction, carpentry, outdoor joinery, flooring, staircases, railway sleepers and boats but also for veneer, inlay, billiard tables, toys, joinery, dowels, shuttles, bobbins, spindles, sporting goods and paddles. As the wood is resistant to marine borers it was used in temperate regions for marine constructions such as piers and sluice gates. In the Herault region in France it was used for years in the construction of waterwheels for irrigation. The wood is also used as fuel.

The heartwood is the source of the so-called true barwood dye. In Africa nowadays, the dye is still used to colour red fabrics, fibres and clothes, including the tail-like ornaments made from raffia fibre in Cameroon and worn on the back by women of the Bulu people. In DR Congo, in the former kingdom of Kuba, at the confluence of the rivers Kasai and Sankuru, the dyes of the famous 'Kasai velvets' include *Pterocarpus soyauxii* reds with a more violet shade, obtained by combining the red dye with tannin-rich plants and a mordant of iron-rich mud.

A pomade is made by mixing the red wood powder with oil and its use as a body cosmetic is widely applied in DR Congo ('ngula'). The roots can be prepared and used in the same way as the heartwood and yield a dye of equal or better quality. Pulverized bark, mixed with palm oil, is also used as a cosmetic pomade. The leaves are eaten as a cooked vegetable.

The powdered wood, baked with a slice of lime, is used in Gabon on wounds and, mixed with palm oil, raffia oil or vegetable butter (e.g. from seeds of *Tieghemella africana* Pierre), to treat skin diseases, ringworm and yaws. Probably partly due to its blood-red colour and the associated symbolism, it is also used in ritual ceremonies for circumcision, initiation, marriage, delivery and widowing. The bark contains a kino type resin ('dragon's blood') which is very astringent and used to ward off skin parasites in ethnoveterinary medicine. In Gabon the resin is used (usually in combinations with parts of other plant species) as an enema to treat dysentery and against toothache, gonorrhoea and excessive menstruation. In Congo and the Central African Republic a bark decoction is drunk to treat dysmenorrhoea, uterine haemorrhage, dysentery and haemorrhoids. A pulp obtained by scraping the inner surface of the bark is applied as a wet dressing against inflammations, oedemas, incipient hernia and whitlow. Decoctions, draughts or vapour-baths of leaves and bark are taken against broncho-pulmonary affections.

Production and international trade In Gabon *Pterocarpus soyauxii* is among the 10 most important export timbers. In Gabon, where the standing stock was estimated at 15 millions m³ in 1999, the minimum diameter limit for exploitation is 70 cm. Between 2000 and 2003, Gabon exported 120,000 m³ of African padauk logs each year, whereas in 1997 the export was only 57,000 m³. Cameroon, where the export of logs is prohibited, exported 6,500 m³ of sawn timber in 2003. The domestic use of the timber is high. In North America African padauk is available as lumber and veneer, and prices are high. In Europe sawn timber and veneer are available on a limited scale only.

Formerly the heartwood of *Pterocarpus soyauxii* was exported in great quantities in standard blocks as red dyewood from Cameroon and Gabon to Europe and North America and used in the wool-cloth and printed cotton industries. Because of its colour fastness, it continued to be used to dye wool-cloth until the beginning of the 20th century in the United States, and in England and France (particularly Elbeuf) to produce brick reds and red-browns or to give a ground for greys and blacks dyed with logwood. As a dye for cotton-cloth, *Pterocarpus soyauxii* with a tin mordant gave the traditional red colour of the printed bandanas that were so popular in England in the 19th century. The resinous consistency of the dye gave the handkerchiefs added weight, characteristic of these items.

Properties *Pterocarpus soyauxii* wood is a moderately heavy hardwood. The heartwood is bright red when freshly cut, becoming orange-red on exposure and darkening to purple-brown, and distinctly demarcated from the whitish to brownish yellow sapwood 6–10(–20) cm wide. The density is (650–)675–815(–900) kg/m^3 at 12% moisture content. The grain is straight to interlocked, texture coarse. At 12% moisture content, the modulus of rupture is 65–128 N/mm^2, modulus of elasticity 12,065–15,870 N/mm^2 and compression parallel to grain 54–64 N/mm^2. The shrinkage rates are moderately low, from green to oven dry 3.2–3.3% radial and 5.0–5.2% tangential. The wood dries well but moderately slowly, with little risk of distortion. Once dry, it is very stable. It is moderately difficult to work. Stellite-tipped sawteeth are recommended. The wood takes a good finish, but sometimes with some tearing of interlocked grain. Slicing does not cause problems, and the wood holds nails and screws satisfactorily; however, pre-boring for screwing is advisable. The gluing properties are good. The dry sawdust may cause irritation to skin, nose and bronchia. The heartwood is durable and also resistant to fungi, *Lyctus* beetles, termites and marine borers; it is moderately difficult to impregnate with preservatives. The sapwood is less durable and moderately difficult to impregnate. The heartwood is rich in extractive substances by organic solvents. The ash, lignin and cellulose contents are moderate. Pentosane content is very low, similar to coniferous wood. Silica content is also very low. The vibration damping factor of the wood is 0.004–0.007 at frequencies of 200–500 Hz. The wood has little moisture uptake; in given conditions, its moisture content is nearly half that of 'standard' woods.

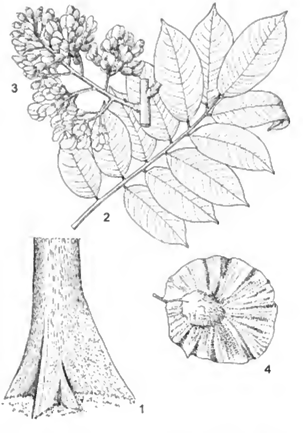
The heartwood of *Pterocarpus soyauxii* contains the red biflavonoids santalin A, santarubin A and santarubin B, isoflavonoids including pterocarpin, formononetin and prunetin, the isoflavanequinone claussequinone and the isoflavanes vestitol and mucronulatol. The low damping factor, shrinkage coefficient and moisture uptake of padauk heartwood appear to be linked to its specific composition in extractive substances, and sapwood has much higher values of these physical properties.

The wood is also rich in tannins, which contribute to mordanting in the dyeing process. In the Colour Index barwood is cited as a source of natural red No 22. Santalin is a histological dye, comparable in use to haematoxylin. In combination with an acid Fe or Al mordant, it selectively dyes cell nuclei, elastic tissues and striations in voluntary muscle fibres.

The leaves have a high ascorbic acid content even after cooking. The bark of *Pterocarpus soyauxii* showed antifungal activity against some pathogenic fungi.

Adulterations and substitutes The wood of *Pterocarpus osun* Craib from southern Nigeria and Cameroon, *Pterocarpus tessmannii* Harms from Equatorial Guinea, Gabon and DR Congo, and *Pterocarpus tinctorius* Welw. from DR Congo and Angola are also marketed as African padauk. The dye of *Pterocarpus soyauxii* may be substituted for by the dyes of other insoluble redwoods, the best known of which are sandalwood (*Pterocarpus santalinus* L. from southern India), narrawood (*Pterocarpus indicus* Willd. from the Philippines and Myanmar) and camwood (*Baphia nitida* Lodd. from West Africa).

Description Evergreen, sometimes deciduous large tree up to 55 m tall; bole straight and cylindrical, branchless for up to 20(–30) m, up to 140(–200) cm in diameter, slightly to prominently and highly buttressed; bark grey-brown to brown, peeling off in thin irregular flakes, exuding a red gum abundantly on slashing; crown dome-shaped, open; twigs brown hairy when young. Leaves alternate, imparipinnately compound with 7–17 leaflets; stipules linear, up to 2 cm long, hairy, falling off early; petiole 1–3.5 cm long, rachis 3.5–16.5 cm long, densely brown hairy; petiolules 3–5 mm long, shallowly furrowed; leaflets alternate to nearly opposite, obovate to elliptical, 2.5–9 cm × 1.5–4 cm, base rounded to obtuse, apex usually abruptly acuminate and mucronate, leathery, glabrous, with closely set, fine and obscure lateral veins. Inflorescence an axillary or terminal much-branched panicle 10–35 cm long, densely brown hairy; bracts linear, falling off at anthesis. Flowers bisexual, papilionaceous; pedicel 3–19 mm long, hairy; calyx campanulate, c. 7.5 mm long, densely hairy, with 5 triangular teeth 1–2.5 mm long, upper 2 more or less connate; corolla with clawed petals, bright yellow or orange-yellow, standard almost circular up to 13 mm × 10 mm, wings up to 12 mm long, keel up to 9.5 mm long; stamens 10, connate



Pterocarpus soyauxii – 1, base of bole; 2, leaf; 3, inflorescence; 4, fruit.
Redrawn and adapted by Iskak Syamsudin

into a sheath up to 8.5 mm long, the upper stamen sometimes free; ovary superior, 1-celled, stalked, white hairy, style up to 4 mm long, glabrous, stigma terminal. Fruit a circular, flattened, indehiscent pod 4.5–9 cm in diameter, on a stalk up to 1 cm long and with a papery, finely veined wing with wavy or plaited margin, finely hairy, glossy brown, 1-seeded. Seed kidney-shaped, flat to slightly thickened, 12–16 mm × 5–7 mm, smooth, red when fresh, turning dull brown to black.

Other botanical information *Pterocarpus* is a pantropical genus belonging to the tribe *Dalbergieae*, comprising 21 species of which 12 occur in Africa, 6 in America and 5 in Asia. Several Asiatic and African species were important commercial sources of red dyes but most species are now much more valuable for timber. The bark of most species yields a reddish medicinal resin of 'kino' type.

Pterocarpus tessmannii Harms is often confused with *Pterocarpus soyauxii*. It has similar wood and dye uses and properties, but grows in wetter parts of the forest. It can be distinguished by its winged, sickle-shaped to oblong fruits 11.5–13.5 cm × 4–5 cm.

Anatomy Wood-anatomical description:

- Macroscopic characters:
  Heartwood orange to bright red with darker streaks when freshly cut, darkening to purple-brown on exposure, and distinctly demarcated from the whitish to brownish yellow sapwood 6–10(–20) cm wide. Grain straight to interlocked. Texture coarse. Wood with faint aromatic scent when freshly cut.
- Microscopic characters:
  Growth rings indistinct. Vessels diffuse, 1–2/mm², in radial multiples of 2–3, mean tangential diameter 115–300 μm; perforations simple; intervessel pits alternate, 8–13 μm in diameter, vestured; vessel-ray pits similar to intervessel pits, but sometimes with apparently simple borders; orange-brown deposits in heartwood vessels present. Fibres 1035–1660 μm long, medium-thick walled. Axial parenchyma banded, apotracheal and paratracheal; apotracheal parenchyma diffuse-in-aggregates, paratracheal parenchyma aliform and confluent. Rays 12–17/mm, exclusively uniseriate, up to 500 μm high, homocellular, with procumbent cells. Prismatic crystals present in chambered axial parenchyma cells. Vessel elements, fibres, axial parenchyma strands and rays distinctly storied.

Growth and development In the Lope reserve in Gabon the trees flower from December–February and the fruits, produced in great quantity, ripen from January–April. Sometimes the tree is deciduous just before flowering. The winged fruits are dispersed by wind, but also by animals. Germination and seedling growth are rather fast. In plantations the annual increment of the wood in Nigeria has been estimated at 40 m³/ha. In trial plantations of 1.5 ha in Côte d'Ivoire in 1964 and 1968, striplings were transplanted at spacings of 4 m × 4 m and 5 m × 5 m. The first 7 years, annual height growth varied between 1.6 m and 2.7 m. The mean annual volume growth, including thinnings, was 20–30 m³/ha over a period of 15 years. The average annual diameter growth of the 150 largest trees per ha was 2.5 cm when 17 years old. *Pterocarpus soyauxii* fixes nitrogen in its root nodules.

Ecology *Pterocarpus soyauxii* occurs scattered or in small groups in evergreen and deciduous forest, from sea-level up to 500 m altitude. It prefers a moist but well-drained deep soil, an average annual rainfall of 1500–1700 mm and an average annual temperature of 23°C.

Propagation and planting Propagation by seed is easy. The seeds are dried in the sun and the wings are removed. In Congo germination started 3 days after sowing and 92% of the seeds germinated within 30 days. In a test in Nigeria, 86% of the seeds with fruit wall removed and soaked overnight in water germinated in 7 days. The germination is hypogeal. Planting into the field is done about 40 days after sowing and is easy. Propagation by non-woody cuttings in normal topsoil gave 83% success. Seedling growth showed a greater response after inoculation of the soil with fungi from the rhizosphere of the mother tree than after inoculation with a similar spore number of fungi from a fallow field.

Management *Pterocarpus soyauxii* requires much light for good growth. Stump regrowth is weak and uneconomic for wood production.

Harvesting Logs are liable to brittle heart. For dye extraction, preferably old and hollow trees are cut from the forest and the heartwood is lumbered out. Often trees are felled and left for 2–3 years lying on the forest floor before taking the heartwood for dyeing purposes. The roots are also harvested for dye extraction.

Handling after harvest Freshly felled logs of *Pterocarpus soyauxii* usually do not float in water, and consequently cannot be transported by river. For dye production the heartwood is split into billets and chips which are dried and subsequently pounded into powder. A little oil is added to the pulverized material, which is moulded into cakes for stocking and for local sale. For dye export the heartwood is traded in standard blocks or bars ('barwood'), making quality control easier.

Since the colorants present in the wood are difficult to dissolve in water, special methods of extraction were developed in the dyeing industry in 19th century Europe, boiling the wood for 1.5–2 hours in a solution of 45° alcohol or in water and carbonate of soda (30 g per 100 g of fibre to be dyed). This solution was then diluted with water and used as the dye bath.

Genetic resources *Pterocarpus soyauxii* is rather widespread in Central Africa and current exploitation rates do not seem to endanger the species. To safeguard genetic variability, protection measures of some natural forest where *Pterocarpus soyauxii* occurs are recommended.

Prospects *Pterocarpus soyauxii* is a useful multipurpose tree from forest areas in Central Africa, producing good-quality timber, dye, vegetables and medicine. Over-exploitation endangers natural populations. More research is needed on growth requirements. Solutions to make better use of and more profit from the chips, sawdust and bark as by-products of the timber, e.g. for dye-extracts and medicinal applications, should be encouraged. As it is quite a fast growing, nitrogen fixing and light demanding tree, it might be useful for agroforestry purposes (e.g. as shadow tree in coffee plantations). The feasibility of establishing commercial plantations also deserves research.

Major references Burkill, 1995; Cardon, 2003; Centre Technique Forestier Tropical, 1978; Raponda-Walker & Sillans, 1961; Rojo, 1972; Surowiec, Nowik & Trajanowicz, 2004; International Centre for Research in Agroforestry (ICRAF), undated b.

Other references Arnone et al., 1977; Bannerjee & Mukherjee, 1981; Brémaud et al., 2004; Carrington, 1976; Duke, 1981; Evrard, 1988; Hauman et al., 1954; Kiec-Swierczynska et al., 2004; Kouablan & Beligne, 1981; Laine et al., 1985; Nzokou & Kamdem, 2003; Okafor, Okolo & Ejiofor, 1996; Osho & Ajonina, 1991; Oslisly, 1999; Pangou, 1982; Richter & Dallwitz, 2000b; Rojo & Alonzo, 1993; White & Abernethy, 1997.

Sources of illustration Wilks & Issembé, 2000; Engler, 1910.

Authors P.C.M. Jansen

PTEROLOBIUM STELLATUM (Forssk.) Brenan

Protologue Mem. New York Bot. Gard. 8: 425 (1954).

Family Caesalpiniaceae (Leguminosae – Caesalpinioideae)

Vernacular names Kantuffa, redwing (En). Mutanda (Sw).

Origin and geographic distribution *Pterolobium stellatum* is widespread in Africa, where it is found from Sudan and Eritrea southwards throughout Central, East and southern Africa to South Africa, but not in Angola, Namibia and Botswana. It also occurs in Yemen.

Uses In Ethiopia, since historical times, the infusion of the pounded bark of *Pterolobium stellatum*, has been a major ingredient for tanning Morocco leather at the same time giving it a bright red colour. It is already mentioned by European travellers in the 19th century. The crushed leaves also yield a dark red dye for leather; ground and boiled in water to which a little oil or butter has been added to help fix the colour, they are also used to dye clothes for mourning, for dark colours in basketry and to colour mats made from doum palm (*Hyphaene thebaica* (L.) Mart.) leaves. Formerly the leaves were one of the main ingredients for making black ink, based on the chemical reaction of the tannins of the plant with iron slag or iron filings from the blacksmith. This ink is water resistant and was used by the famous plant collector G.W. Schimper around 1840 to write the labels of his Ethiopian plants. Leather is dyed black by treatment with a mixture of dried leaves and iron filings (iron-oxide) in water.

Pterolobium stellatum is also used for firewood and fodder, and as live fence and ornamental. Because of the sharp, recurved prickles, branches are used to make rat traps. *Pterolobium stellatum* is sometimes planted to combat the weedy cactus *Opuntia*. In traditional medicine in East Africa, fresh leaves are chewed or a decoction is drunk to treat tuberculosis and related respiratory diseases. In Kenya a root decoction is used by the Maasai against stomach-ache. Juice of the roots is swallowed to treat snakebites. In Malawi a root infusion is drunk by women against infertility.

Properties The leaves of *Pterolobium stellatum* contain approximately 20% tannin. Neither the tannins of bark and leaves nor their dye content appear to have been investigated and characterized.

Botany Climbing or straggling shrub, with stems up to 15 m long, armed with recurved prickles. Leaves alternate, with small, early caducous stipules, bipinnately compound with 5–13 pairs of pinnae; rachis armed with paired recurved prickles and often also solitary straight ones; leaflets 7–16 pairs per pinna, oblong or elliptical-oblong, 4–12 mm × 2–5 mm, pubescent to glabrous. Inflorescence a dense raceme 5–18 cm long, aggregated into extensive terminal panicles up to 35 cm × 20 cm. Flowers bisexual, slightly zygomorphic, 5-merous, small, sweetly scented, pale yellow or whitish; pedicel 3–6 mm long; sepals 2–3 mm long, unequal, the lower one hood-shaped and embracing the others, pale green; petals almost equal, oblanceolate-oblong, c. 3 mm × 1.5 mm, pubescent towards base; stamens 10, filaments alternately longer and shorter, 4–5 mm long, pubescent below; ovary superior, 1-celled, style gradually enlarged near apex, stigma transverse. Fruit a brick-red to scarlet, ultimately brown, winged pod, with a stalked, 1-seeded basal portion 3–6 cm long and a much prolonged upper suture broadly winged on its lower side; wing 2–4.5 cm × 1–1.5 cm. Seed ovoid-ellipsoid, c. 11 mm × 6.5 mm, olive-green. *Pterolobium* belongs to the tribe *Caesalpinieae* and comprises about 10 species, 9 occurring in Asia and only a single one in Africa.

Ecology *Pterolobium stellatum* is a common shrub, forming thickets in margins and clearings of upland dry evergreen forest, *Acacia* woodland and riparian formations, mainly at 500–2500 m altitude.

Management The leaves are mostly collected from the wild, but *Pterolobium stellatum* is also cultivated and then propagated by seed, cuttings or wildlings. The seeds germinate better when they are scarified mechanically or chemically. They are sensitive to high temperatures, so hot water treatment before germination is not recommended. The seeds can be easily stored in airtight containers for more than a year without loss of viability. Hedges of *Pterolobium stellatum* plants are impenetrable because of the sharp prickles and can be pruned to a desired height and width.

Genetic resources and breeding *Pterolobium stellatum* is widespread and common in many regions, and not in danger of genetic erosion. Germplasm collections are not known to exist, although some companies offer seeds for sale.

Prospects *Pterolobium stellatum* being a widespread multipurpose plant, interesting both as ornamental bush and as impenetrable live fence, could represent a good renewable source of red dye that does not need a mordanting process due to the associated action of tannins. Its medicinal properties are in need of investigation.

Major references Bein et al., 1996; Brenan, 1967; Gelfand et al., 1985; Roti-Michelozzi, 1957; Tournerie, 1986.

Other references Beentje, 1994; Getahun, 1976; Jansen, 1981; Kokwaro, 1993; Teketay, 1998; Thulin, 1989; Vidal & Hul Thol, 1974; Wilczek et al., 1952.

Authors P.C.M. Jansen

PYRANTHUS TULLEARENSIS (Baill.) Du Puy & Labat

Protologue Kew Bull. 50: 81–82 (1995).

Family Papilionaceae (Leguminosae - Papilionoideae, Fabaceae)

Origin and geographic distribution *Pyranthus tullearensis* is an endemic of south-western Madagascar and is confined to the

Isalo Massif and the upper Onilahy River valley.

Uses The bark of *Pyranthus tullearensis* is made into a yellow paste or powder, used by Bara women as a skin cosmetic.

Botany Shrub or small tree up to 4 m tall, with trunk up to 10 cm in diameter; young twigs densely yellow-white pubescent, turning black-grey. Leaves alternate, imparipinnately compound with 11–25 leaflets; stipules slender; leaflets oblong-elliptical, 10–23 mm × 4–11 mm, base rounded, apex rounded but mucronate, leathery, densely white-hairy beneath. Inflorescence a terminal or axillary false raceme. Flowers bisexual, papilionaceous, 10–12 mm long; calyx tubular, 4–5 mm long, with 5 equal teeth, the upper pair partially connate; corolla scarlet-red, standard almost circular, 10–13 mm × 8–12 mm, somewhat whitish-pubescent, with an irregular white basal eye, wings shallowly curved, darker along the upper margins, keel falcate; stamens 10, filaments fused into staminal sheath 9–13 mm long, strongly curved; ovary superior, 1-celled, sessile, style slender, stigma punctate. Fruit a flattened pod 6–8 cm × 7–8 mm, almost glabrous to silky hairy, opening with 2 strongly spiralling valves, several-seeded. Seeds compressed-reniform, 6 mm × 4 mm, brown.

Pyranthus comprises 6 species, all endemic to Madagascar. It is classified in the tribe *Millettieae* and is somewhat intermediate between the related genera *Mundulea* and *Chadsia*. *Pyranthus tullearensis* has been subdivided into 2 subspecies, based on the hairiness of the fruits and the size of the flowers.

Ecology *Pyranthus tullearensis* grows on sandstone rock outcrops, in grassland and open woodland, at 500–1100 m altitude. It is somewhat resistant to grassland fires and flowers in October–February.

Genetic resources and breeding *Pyranthus tullearensis* is not very widespread and although it shows some fire resistance, habitat destruction by bush fire may endanger it eventually. Germplasm collection and protection measures are recommended.

Prospects *Pyranthus tullearensis* as source of a dye is only very locally of some importance in Madagascar, and this will probably not change in the future.

Major references du Puy et al., 2002.

Other references du Puy & Labat, 1995.

Authors P.C.M. Jansen

RHUS TOMENTOSA L.

Protologue Sp. pl. 1: 266 (1753).

Family Anacardiaceae

Vernacular names Wild currant, furry rhus, hairy taaibos (En). Sumac (Fr).

Origin and geographic distribution *Rhus tomentosa* is found in eastern Zimbabwe and eastern and southern South Africa.

Uses The wood, bark of roots and branches, and leaves of *Rhus tomentosa* are collected from the wild and used in tanning. The bark also produces fibre for rough rope. The wood is hard and tough, but it is only used as fuel because the trees are small. The fruits are edible, but of very poor flavour. *Rhus tomentosa* is an attractive shrub with potential as an ornamental and seed is available from specialist suppliers. It was one of the first *Rhus* species introduced into botanical gardens.

Properties The leaves of *Rhus tomentosa* yield 8% tannin and the twigs 5.7%. The bark is rich in tannic acid.

Botany Dioecious shrub or small tree up to 5 m tall, much-branched; bark smooth, grey-brown; branches shallowly ridged, densely red-hairy when young, older ones dark green. Leaves alternate, 3-foliolate; stipules absent; petiole up to 4 cm long; leaflets lanceolate-elliptical to obovate, 3–9 cm × 1–4 cm, terminal leaflet largest, base broadly tapering, margin entire or in upper part with 1–3 small teeth, leathery, yellowish to whitish hairy below. Inflorescence a lax, much-branched, axillary or terminal panicle, male one up to 9 cm long, female one up to 5 cm long. Flowers unisexual, regular, 5-merous; pedicel 1–2 mm long; calyx with ovate segments; petals c. 1 mm long; male flowers with 5 stamens; female flowers with superior, globose, 1-celled ovary, styles 3, stigmas headlike. Fruit a globose drupe 4–6 mm × 3–4 mm, densely grey-tomentose.

Rhus comprises about 200 species, of which about 110 occur in Africa. Subtropical southern Africa is richest in species (about 80), and about 50 species occur in tropical Africa. The African species belong to subgenus *Thereza*, characterized by 3-foliolate leaves, flowers in panicles or racemes, resinous mesocarp of fruit adhering to the bony endocarp, and absence of toxicity.

Other African *Rhus* species are used occasionally for dyeing: the bark of *Rhus lancea* L.f. gives a brown dye, that of *Rhus pendulina* Jacq., more reddish-brown colours. The bark of *Rhus undulata* Jacq. is a traditional source of tannin in Namaqualand (South Africa) and the root of *Rhus ciliata* Licht. ex Roem. & Schult., the wood of *Rhus lancea* and the bark and wood of *Rhus lucida* L. have also been used for tanning. However, these species are more important for their edible fruits and/or timber.

Ecology *Rhus tomentosa* grows on rocky mountain slopes and on edges of low bushland vegetation, up to 2500 m altitude.

Genetic resources and breeding *Rhus tomentosa* does not seem to be in danger of genetic erosion.

Prospects Most probably *Rhus tomentosa* will remain important for tanning only very locally. Possibly it will become more important as an ornamental.

Major references Coates Palgrave, 1983; Fernandes & Fernandes, 1966; van Wyk & Gericke, 2000.

Other references Moffett, 1993; Palmer & Pitman, 1972–1974; Schonland, 1930; Watt & Breyer-Brandwijk, 1962.

Authors P.C.M. Jansen

ROTHMANNIA LONGIFLORA Salisb.

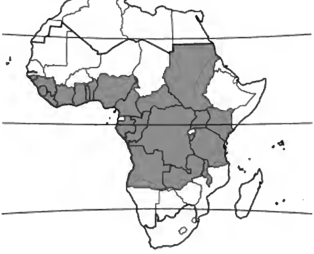
Protologue Parad. lond., 1(2): t. 65 (1807).

Family Rubiaceae

Synonyms *Randia maculata* DC. (1830).

Origin and geographic distribution *Rothmannia longiflora* is found from Gambia east to Sudan and Kenya, and south to Tanzania and Angola.

Uses The fruits of *Rothmannia longiflora* are commonly used to make blue-black markings on the hands, face and body, sometimes to imitate tattooing. In Central and East Africa fibres of vegetable origin (e.g. of *Raphia*) are coloured by soaking them in swamp mud to which fruits and leaves of *Rothmannia longiflora* have been added. In Nigeria a dye and an ink-like extract ('katambiri') is made from finely crushed seeds. To make a stronger dye and ink, the extract is sometimes mixed with leaves of *Gardenia*, *Indigofera*, *Nauclea* or *Vitex* and sugar or honey. A black dye can be prepared from the flowers.



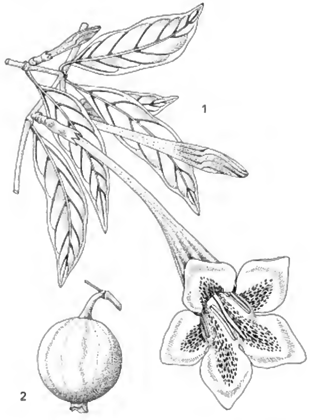
Rothmannia longiflora – wild

The fruits are edible. In Sierra Leone the stems are used to make shafts of a long-handled chisel ('sundi') used for harvesting fruit bunches of oil palm and elsewhere to make spear handles. In Ghana twigs are used as chewsticks. *Rothmannia longiflora* is considered to have febrifugal and analgesic properties, and a decoction of the leaves, twigs, bark and roots is applied internally or externally in lotions, washes and baths. In Nigeria the roots are used to treat bowel complaints. In DR Congo a root infusion is applied as a treatment for throat abscesses, toothache and leprosy. In West Africa leaf pulp is used as an enema against kidney pain and diarrhoea with blood, and drinking the leaf juice is said to help during labour and childbirth. In Sierra Leone leaves are used to treat itching skin diseases and the fruit pulp is said to be emetic. In DR Congo the seed is used to treat ulcers. *Rothmannia longiflora* is a decorative plant with large, attractive, trumpet-shaped, white or pink flowers and is worth cultivating as an ornamental.

Production and international trade *Rothmannia longiflora* is collected from the wild and is traded only locally. On markets the fruits are often traded with the rind removed or as broken pieces with adhering seeds.

Properties No specific chemical study of the colorants or dye-precursors present in the flowers, fruits or leaves is available for *Rothmannia longiflora*. From the fruits, branches and leaves however, 4-oxonicotinamide-1-(1'-β-D-ribofuranoside) has been isolated. This N-glycoside is only known from human urine and has never been isolated from other higher plants. It is an interesting compound, particularly in influencing enzymatic processes. The fruits also contain monomethyl fumarate (used to treat psoriasis) and D-mannitol which is used as a nutrient, dietary supplement and a texturizing agent. Due to its low hygroscopicity, D-mannitol is often used as a dusting powder to protect products against moisture pick-up. A major use of D-mannitol is in chewing gum and it is also widely used in intestinal permeability tests.

Description Shrub or small tree up to 9 m tall, often with climbing stems. Leaves opposite, simple and entire, glabrous; stipules triangular, c. 3 mm long, early caducous; petiole 3–10 mm long; blade elliptical, 6–18 cm × 2–8 cm, base cuneate, apex acuminate, pinnately veined with 4–5 pairs of lateral veins having axillary domatia. Flowers solitary, terminal on short axillary branches, bisexual, regular, 5-merous, sweetly scented; pedicel up to 1 cm long, bearing 5–9 scale-like bracteoles; calyx tubular, 1–2 cm long, lobes triangular, 1–4 mm long; corolla trumpet-shaped, up to 24 cm × 4 cm, lobes ovate, 1–4 cm × 1–1.5 cm, purple-red to green outside, whitish with purplish spots inside; stamens inserted in the corolla tube, included or with tips of anthers exserted; ovary inferior, 2-celled, style 12–21 cm long, stigma 2-lobed, up to 3 cm long, partly exserted. Fruit a globose to ellipsoid berry, 3.5–7 cm × 5–6 cm, green-blackish, with 10 indistinct ribs, glabrous, many-seeded, the calyx persistent. Seeds lens-shaped, 6–8 mm × 5–6 mm × 1–1.5 mm, brown-red.



Rothmannia longiflora – 1, flowering branch; 2, fruit.
Redrawn and adapted by Achmad Satiri Nurhaman

Other botanical information *Rothmannia* comprises about 30 species, distributed in tropical Africa, Madagascar and Asia. In tropical Africa about 18 species are present.

The following *Rothmannia* species, also occurring in tropical Africa, have or most probably have, similar dye, medicinal and ornamental uses:

- *Rothmannia engleriana* (K.Schum.) Keay, small tree with fruits 2–5 cm long, found in Angola, DR Congo, Zambia, Malawi, Mozambique, Tanzania and Burundi; the ripe fruit is edible, it is juicy, sweet and aromatic; an infusion of the roots is used against stomachache and snakebite; the wood is used as firewood and to make tool handles and spoons.
- *Rothmannia fischeri* (K.Schum.) Bullock, shrub or small tree up to 8 m tall, fruits 3–6 cm long, found in Kenya, Tanzania, DR Congo, Malawi, Zambia, Zimbabwe and South Africa.
- *Rothmannia hispida* (K.Schum.) Fagerl. (syn.: *Randia hispida* K.Schum.), shrub or small tree up to 10 m tall, fruits 6–11 cm long, occurring from Guinea to DR Congo; the wood on cutting and exposure to the air takes on a blue colour; in Nigeria, leaf sap and fruit juice are used to draw black designs on the body and to blacken tattoos; mixed with palm oil, they are applied on the skin against fungal infections.
- *Rothmannia lateriflora* (K.Schum.) Keay, shrub or small tree up to 8 m tall, fruits cylindrical, 5-ribbed, up to about 6 cm × 4 cm, occurring in Cameroon, Gabon and DR Congo; among the Mongo of DR Congo, the juice of the fruit is used to blacken tattoos.
- *Rothmannia lujae* (De Wild.) Keay (syn.: *Randia coriacea* K.Schum. ex Hutch. & Dalziel), tree up to 30 m tall, fruits 15–20 cm long, occurring from Nigeria to DR Congo; seeds are used in Nigeria to make a dye used by women for painting patterns on the skin; a bark decoction is drunk against abdominal troubles; the bark, leaf and root contain some tannin.
- *Rothmannia macrosiphon* (Engl.) Bridson, shrub or small tree up to 7 m tall, fruits 2–3 cm long, occurring in Kenya and Tanzania; the fruit yields a blue-black dye.
- *Rothmannia manganjae* (Hiern) Keay, shrub or small tree up to 15 m tall, fruits 2–4 cm long, occurring in Kenya, Tanzania, Mozambique, Malawi and Zimbabwe. This species closely resembles *Rothmannia longiflora* but has a much shorter corolla; sterile or young flowering specimens of both species are particularly hard to distinguish.

- *Rothmannia munsae* (Schweinf. ex Hiern) Petit (syn.: *Randia megalostigma* (Wernham) Keay, *Randia lane-poolei* Hutch. & Dalziel), shrub or tree up to 17 m tall, fruits up to 7 cm long, occurring from Sierra Leone to Cameroon and DR Congo.
- *Rothmannia octomera* (Hook.f.) Fagerl., shrub or small tree up to 2 m tall, flowers 7–8-merous, fruits subcylindrical, up to 14 cm long, occurring from Nigeria to DR Congo; in DR Congo and Nigeria, the fruit juice is used to draw black designs on the body and to blacken tattoos; pulped roots are applied against pneumo-bronchial troubles in Congo.
- *Rothmannia urcelliformis* (Hiern) Robijns, shrub or small tree, up to 15 m tall, fruit up to 10 cm long, widespread all over tropical Africa; in Ethiopia, in the province of Illubabor, the fruits are crushed and boiled in water to obtain a blue dye for cloth; they contain the iridoid alkaloid gardenamide A; fruits are said to be poisonous and have some molluscicidal property; powdered dry fruits are used alone or mixed into a hunting poison in Central African Republic.
- *Rothmannia whitfieldii* (Lindl.) Dandy (see separate treatment).

Growth and development Fruiting of *Rothmannia longiflora* plants is about 3 months after flowering.

Ecology *Rothmannia longiflora* is found in the undergrowth of primary as well as secondary forest, from sea-level up to 1700 m altitude.

Management In cultivation *Rothmannia longiflora* can easily be propagated by seed.

Genetic resources *Rothmannia longiflora* is widespread and common, and is not in danger of genetic erosion.

Prospects *Rothmannia longiflora* is easy to grow and has interesting dye, medicinal and ornamental properties. More research is needed to evaluate its commercial and agricultural possibilities.

Major references Abbiw, 1990; Bridson & Verdcourt, 1988; Burkill, 1997; Dalziel, 1937; Holland, 1908–1922; Irvine, 1961.

Other references Beentje, 1994; Bringmann et al., 2001; Bringmann et al., 1999; Hallé, 1970; Hepper & Keay, 1963; Hulstaert, 1966; Neuwinger, 1998; Neuwinger, 2000; Ruffo, Birnie & Tengnäs, 2002; Sonké & Simo, 1996; Tournerie, 1986.

Sources of illustration Irvine, 1961; Hallé, 1970.

Authors P.C.M. Jansen

ROTHMANNIA WHITFIELDII (Lindl.) Dandy

Protologue F.W.Andrews, Flow. pl. Anglo-Aegypt. Sudan 2: 461 (1952).

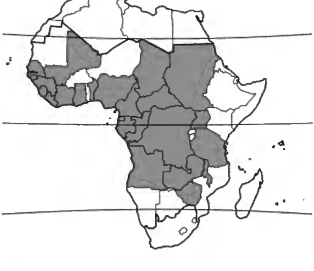
Family Rubiaceae

Synonyms *Randia malleifera* (Hook.) Hook.f. (1873).

Origin and geographic distribution *Rothmannia whitfieldii* is widespread in tropical Africa, from Senegal east to Sudan, and south to Angola and Zimbabwe.

Uses The fruit juice and fresh seeds contain a blue-black dye, which is widely used in tropical Africa as a cosmetic for body decoration, to mark an outline for tattooing and to rub into tribal markings in the skin to make them more conspicuous. The dye is said to be permanent. To dye barkcloth ('pongo') plain black, or decorate them with designs, the Mbuti, the Efe Pygmies and the Balese cultivators of the Ituri forest in north-eastern DR Congo, warm the soft pulp in the fruit on a fire, crush it and the black liquid obtained is mixed up with charcoal powder for drawing designs. They also change the colour to greyish-blue by adding lemon juice on the entire dyed cloth or on some designs only.

The dye is sometimes employed together with dye prepared from the pods and seeds of *Piliostigma thonningii* (Schumach.) Milne-Redh. It is also used to dye fabrics and as ink. The wood is hard and used for hoe-handles. *Rothmannia whitfieldii* is considered to possess febrifugal, anti-diarrhoeic and ecbolic properties. The fruit juice is applied to sores and wounds to promote healing, and in Tanzania to leprous areas of the skin. In East Africa it is applied to eczema on the toes. Drinking of cold water in which

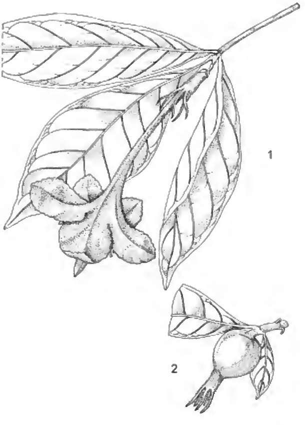


Rothmannia whitfieldii – wild

chips of the root bark have been steeped provokes abundant expectoration and is a relief for asthma. In southern Africa root ash is used as a cicatrizant on wounds and to treat eczema on the toes. In Sierra Leone charred fruits are used to strengthen palm wine. With its large, pendulous, sweet-scented, white or brownish-white flowers *Rothmannia whitfieldii* is potentially an attractive ornamental.

Properties No chemical study of the colorants or dye-precursors present in the flowers and fruits is available for *Rothmannia whitfieldii* but presumably the fruit pulp contains alkaloids with dyeing properties like several other *Rothmannia* species with similar uses. In the bark and leaves alkaloid is present. The bark and root contain saponin. The wood has molluscicidal potential: a water extract kills the freshwater snail *Bulinus globulus* at 100 ppm.

Description Shrub or small tree up to 15 m tall; young stems pubescent. Leaves opposite, simple and entire, leathery; stipules triangular, 2–6 mm long, deciduous; petiole up to 2 cm long; blade elliptical to obovate, 9–29 cm × 3–13 cm, base cuneate, apex acuminate, pinnately veined with 8–15 pairs of lateral veins, almost glabrous. Flowers solitary, pendent, terminal on short axillary branches, bisexual, regular, 5-merous, sweetly scented; pedicel up to 2.5 cm long, red pubescent, bearing 2–6 triangular bracteoles 2.5–3 mm long; calyx tubular, red-brown pubescent, tube up to 2.5 cm long, 10-grooved when dry, lobes linear, up to 8 cm × 4 mm; corolla trumpet-shaped, white, sometimes with purple spots, 7–30 cm long, lobes ovate, 1.5–7 cm × 1.5–8 cm, red-brown pubescent; stamens inserted in corolla tube, included or tips of anthers exserted; ovary inferior, 2-celled, style 7–19 cm long, abruptly widened at the wholly or partly exserted 2-lobed and 3–7.5 cm long stigma. Fruit a globose berry 3–7 cm in diameter, smooth to strongly 10-ribbed, velvety brown pubescent when young but glabrescent, many-seeded, crowned by the persistent calyx. Seeds lens-shaped, 7–11 mm × 3–4 mm.



Rothmannia whitfieldii – 1, flowering branch; 2, fruit.
Redrawn and adapted by Achmad Satiri Nurhaman

Other botanical information *Rothmannia* comprises about 30 species, distributed in tropical Africa, Madagascar and Asia. About 18 species are present in tropical Africa. *Rothmannia whitfieldii* is an extremely variable species, e.g. flowers with long or short tubes occur.

Ecology *Rothmannia whitfieldii* occurs in forest undergrowth, often in old secondary forest, but also in savanna woodland, up to 1700 m altitude.

Genetic resources *Rothmannia whitfieldii* is widespread in tropical Africa and is not in danger of genetic erosion.

Prospects The dye, medicinal and ornamental properties of *Rothmannia whitfieldii* make it an interesting species, deserving more research.

Major references Bridson & Verdcourt, 1988; Burkill, 1997; Dalziel, 1937; Irvine, 1961; Tanno, 1981; Terashima, Ichikawa & Sawada, 1988.

Other references Abbiw, 1990; Andrews, 1952; Gassita et al. (Editors), 1982; Hallé, 1970; Hepper & Keay, 1963; Neuwinger, 2000; Raponda-Walker & Sillans, 1961; Sonké & Simo, 1996; Somers & Robbrecht, 1991.

Sources of illustration Irvine, 1961.

Authors P.C.M. Jansen

RUBIA CORDIFOLIA L.

Protologue Syst. nat. ed. 12, 3 (app.): 229 (1768).

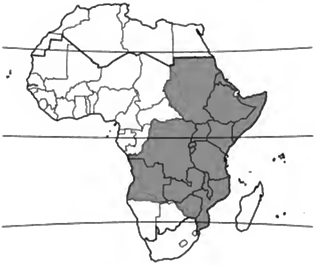
Family Rubiaceae

Chromosome number $2n = 22$

Vernacular names Indian madder, munjeet (En). Garance indienne, manjit (Fr). Ruiva dos tintureiros da Índia (Po). Kifundo, ukakaka (Sw).

Origin and geographic distribution *Rubia cordifolia* has an extremely large area of distribution, ranging from Africa to tropical Asia, China, Japan and Australia. In Africa it is found from Sudan and Ethiopia to South Africa.

Uses *Rubia cordifolia* has been and still is widely used as a dye plant in Asia. In Africa it appears to have been less important as a dye. Its use is only documented in South Africa, where the roots are used to dye wool, and in Ethiopia, where they serve to dye wool and bread baskets into various shades of red, pink, purple or maroon. The roots are an important ingredient in recipes of red inks that may also contain other red dye-plants such as the roots of *Impatiens tinctoria* A.Rich. and the bark of *Osyris quadripartita* Salzm. ex Decne. The juice of crushed fruits is bottled and used as green to bluish ink. Reports from Asian countries (particularly northern India, Bhutan, Nepal, Tibet, China and Japan) show that a red dye extracted from the stems and roots has long been used to dye silk, linen and cotton fabrics (chintz), and wool (blankets and carpets). The red colorants present, though slightly different in chemical composition, give dyes quite similar in hues and fastness to those produced by *Rubia tinctorum* L., the European madder plant. To dye a piece of cloth, it is simmered in a decoction of the root and sometimes of the lower part of the stem in water, after having previously been mordanted with alum and (for chintz) with fatty and tannin mordants. Several synthetic dyes have now largely replaced Indian madder as a source of red dye for industrial production in Asia, but it is still used for high-quality traditional textiles. In Tanzania ash of burnt stems and leaves is used as vegetable salt to soften vegetables when cooking. *Rubia cordifolia* is widely used in African traditional medicine. In Uganda and Tanzania the leaves are used as a poison antidote and to treat mouth sores and intestinal problems such as diarrhoea; a drink prepared from crushed and boiled leaves is administered to patients. Roots are credited with astringent and antidysenteric properties. In South Africa the root is used to treat impotence and as an aphrodisiac. In Tanzania and Kenya a wound dressing ('kiraara') is made by rubbing the leaves between the hand palms into a ball, which is then applied to a wound or cut to stop bleeding and as an antiseptic. A root decoction is used as an emetic in cases of stomach problems. In Rwanda a root decoction is used to treat women who experience weight loss during pregnancy ('ifumbi'), urethral leak, giddiness, tingling sensations and kidney problems. In DR Congo the leaves are burnt and the ashes are used to treat inflammation of the mammary glands (mastitis) in cattle and also to treat itchy skin in humans. In Burundi a leaf decoction is administered to newly born calves with haemorrhagic diarrhoea ('amacikire') and also to treat external parasites such as fleas, ticks and mites in animals. In Ethiopia the leaves are used to treat malaria, itches and to stop bleeding, the roots to treat amoebic dysentery, cancer and cough. The leaves are eaten in Indonesia as a side dish with rice, and fresh fruits are edible. *Rubia cordifolia* can be used as an ornamental climber, but in cultivated fields it can behave as a troublesome weed.



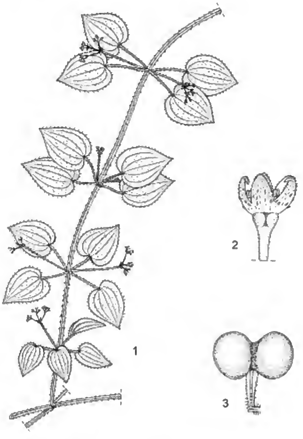
Rubia cordifolia – wild

Production and international trade *Rubia cordifolia* does not appear to have been much cultivated, but was and still is mostly collected from the wild. At present, production and trade for its dye is almost confined to northern India and surrounding countries. In the past, starting at the end of the 18th century, roots were exported to the United Kingdom. Nowadays, powdered Indian madder for dyeing is exported e.g. to Europe, North America and Japan in small amounts that are difficult to quantify. In Africa *Rubia cordifolia* is only occasionally traded on local markets for use in traditional medicine.

Properties The roots are reported by various authors to contain a very large range of yellow to red colorants, mostly anthraquinones in the free or glycosidic states: munjistin, purpurin, pseudopurpurin, purpuroxanthin, rubiadin, lucidin, nordamnacanthal, physcion, 1-hydroxy-2-methyl-anthraquinone, 1-hydroxy-2-methoxy-anthraquinone, 1,4-dihydroxy-2-methyl-anthraquinone, 1,4-dihydroxy-6-methyl-anthraquinone, 1,4-dihydroxy-2-methyl-5-methoxy-anthraquinone, 1,5-dihydroxy-2-methyl-anthraquinone, 1-acetoxy-6-hydroxy-2-methyl-anthraquinone, 1,3-dimethoxy-2-carboxyanthraquinone, 1,3,6-trihydroxy-2-methylanthraquinone. Other minor compounds belonging to different chemical groups (napthoquinones and naphthohydroquinones) have also been isolated from the roots, e.g. 3-prenyl-methoxy-1,4-naphtoquinone, mollugin, furomollugin and dehydro-α-lapchone. Alizarin (1,2-dihydroxy-anthraquinone), the most important colouring agent in the European madder *Rubia tinctorum* L. is present in small quantity in the stems, with purpurin, rubiadin and munjistin as major components. From the roots of *Rubia cordifolia* subsp. *pratensis* (Maxim.) Kitam., collected in China, 11 anthraquinones and their glycosides and 4 naphthohydroquinones (among which dihydromollugin) and their glycosides were isolated. The derivatives of 1,3,6-trihydroxy-2-methylanthraquinone so far isolated are only found in some forms of *Rubia cordifolia* and in *Rubia akane* Nakai from Asia. Differences in the composition of roots and stems to be noticed in the literature point to the need for a systematic chemotaxonomic research on the various forms of the plant, both in Asia and Africa. In India, mollugin showed inhibition of passive cutaneous anaphylaxis and protection of mast cell degranulation in rats. It also exhibited considerable activity against lymphoid leukemia in mice. In tests, the anti-inflammatory activity of an extract of the roots has been demonstrated.

Adulterations and substitutes *Rubia cordifolia* and other *Rubia* species are currently sold together as 'madder'. *Rubia cordifolia* should not be confused with *Oldenlandia umbellata* L., also called Indian madder and found in eastern India, Myanmar and Sri Lanka but not in Africa, which contains alizarin as red dye component.

Description Climbing or creeping perennial herb with stems up to 10 m long, with woody, long, cylindrical, flexuose roots with thin red bark; stem branched, with long internodes, distinctly 4-ribbed, 1.5–3 mm in diameter, with recurved prickles on the 4 ribs. Leaves arranged in whorls of 4, simple and entire; petiole (0.5–)5–12 cm long; blade lanceolate, cordate or ovate, 1.5–6.5(–10) cm × 0.5–4 cm, base cordate or rounded, apex acute or acuminate, margins and veins below with recurved prickles, glabrous to hairy, with (3–)5(–7) prominent veins from the base. Inflorescence an axillary or terminal cyme up to 2.5 cm long, lax or dense; peduncle 1–2.5 cm long. Flowers bisexual, regular, (4–)5(–6)-merous; pedicel up to 6 mm long; calyx obsolete; corolla rotate to campanulate, 3–6 mm in diameter, lobes triangular, greenish-white to yellow; stamens inserted in corolla tube, anthers exserted; disk small, swollen; ovary inferior, 2-celled, styles 2, short, stigmas head-shaped. Fruit consisting of 1–2 globose mericarps 2.5–5 mm in diameter, bluish-black, each with a single seed. Seed globose, 1–3 mm in diameter.



Rubia cordifolia – 1, part of flowering stem; 2, flower; 3, fruit.
Redrawn and adapted by Achmad Satiri Nurhaman

Other botanical information *Rubia* comprises about 60 species and is distributed in Europe, Africa and Asia, with 3 species in tropical Africa. It is closely related to *Galium*. The name *Rubia cordifolia* L. is applied to a vast range of plants distributed all over Africa and Asia. Attempts to split the extremely variable *Rubia cordifolia* into several taxa have failed, and much experimental taxonomic work would be needed to unravel the systematics of this species and its allies. All African material is currently included in subsp. *conotricha* (Gand.) Verdc. (synonym: *Rubia conotricha* Gand.), which is also variable, varying mostly in shape, size and hairiness of the leaf and length of the petiole. In Eritrea, Ethiopia and Somalia the plants have the lower side of the leaves densely covered with white hairs and the corollas are distinctly campanulate. They have been distinguished as var. *discolor* (Turcz.) K.Schum. (synonym: *Rubia discolor* Turcz.). The 2 other species in Africa, *Rubia petiolaris* DC. and *Rubia horrida* (Thunb.) Puff, are confined to southern Africa and differ from *Rubia cordifolia* by having leaves arranged in whorls of 6–8(–12) instead of whorls of 4. *Rubia petiolaris* has been recorded from South Africa and Lesotho and *Rubia horrida* from Zimbabwe, South Africa, Botswana and Namibia.

Ecology *Rubia cordifolia* has a wide ecological adaptability. It is found in forest edges and clearings, scrub vegetation and dune forest, less commonly in grassland or open, rocky areas, from sea-level up to 2600 m altitude.

Propagation and planting *Rubia cordifolia* is occasionally cultivated in India (Darjeeling). It can be propagated by seed, cuttings and micropropagation methods. Seed germinates best when sown immediately after ripening; stored seed takes time to germinate. Plants should be grown in light shade.

In vitro production of active compounds Experimental results from *Rubia cordifolia* cell cultures to produce anthraquinones for pharmaceutical purposes are promising.

Handling after harvest In Africa the roots and stems are harvested exclusively from the wild. They are either used fresh and crushed, or dried and then ground to powder. To prepare the dye bath for wool or basket fibres, water is added to the crushed or ground roots and left to simmer for two hours, then the material to by dyed (pre-mordanted with alum, in the case of wool) is added to the dye-bath. It is allowed to simmer for another hour and left to cool down in the bath before washing and drying.

Genetic resources *Rubia cordifolia* is widely distributed in secondary and disturbed habitats and is unlikely to be liable to genetic erosion. Its extreme variability requires more attention.

Prospects *Rubia cordifolia* has at present lost much of its former importance as a dye-producing plant, but since it produces a great range of beautiful, fast colours and is easy to propagate, the current growing interest in natural dyes as renewable resources may make it a useful crop. Its effectiveness in disease treatments deserves more research and is being investigated in India where the plant was used in the Ayurvedic and Unani systems of medicine, besides being part of an anticancer compound in Tibetan medicine.

Major references Cardon, 2003; Oyen, 1991b; Ruffo, Birnie & Tengnäs, 2002; Sakata & Katayama, 1996a; Sakata & Katayama, 1996b; Tournerie, 1986; Verdcourt, 1976; Verdcourt, 1989.

Other references Bhuyan & Saikia, 2005; Bulgakov et al., 2003a; Bulgakov et al., 2003b; CSIR, 1972; Dosseh, Tessier & Delaveau, 1981a; Dosseh, Tessier & Delaveau, 1981b; Gelfand et al., 1985; Gupta, Gulrajani & Kumari, 2004; Gupta et al., 1999; Jansen, 1981; Kasture, Kasture & Chopde, 2001; Kokwaro, 1993; Puff, 1984; Puff, 2003; Suzuki & Matsumoto, 1988; Takeya et al., 1993; Tessier, Delaveau & Champion, 1981; Tiwari et al., 1999; van Wyk & Gericke, 2000; Verdcourt, 1975b; Vlietinck et al., 1995; Watt & Breyer-Brandwijk, 1962.

Sources of illustration Verdcourt, 1976.

Authors C. Zimudzi

SENNA AURICULATA (L.) Roxb.

Protologue Fl. ind. ed. 1832, 2: 349 (1832).

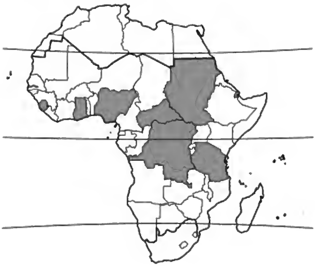
Family Caesalpiniaceae (Leguminosae – Caesalpinioideae)

Chromosome number $2n = 14, 16, 28$

Synonyms *Cassia auriculata* L. (1753).

Vernacular names Avaram, tanner's cassia, tarwar (En). Avaram (Fr). Avúl (Po).

Origin and geographic distribution *Senna auriculata* is a native of India, Myanmar and Sri Lanka and has been successfully introduced into several African countries. It has been suggested that it is indigenous in Tanzania, but an early introduction and naturalization seem more likely. It is cultivated in India and Sri Lanka, and occasionally elsewhere.



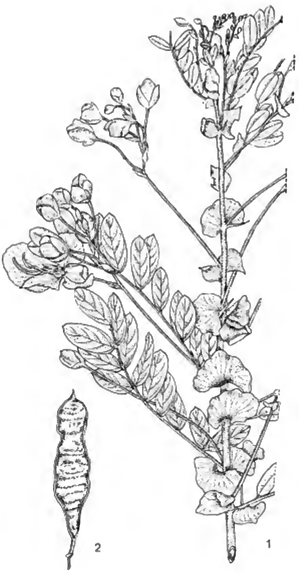
Senna auriculata – planted and naturalized

Uses *Senna auriculata* is a multipurpose plant. The bark can be used for tanning heavy hides and goat and sheep skins, giving a buff-coloured leather of good quality, which tends to darken to black-red on exposure to light. To prevent this darkening the leather is often finished by a tannage using myrobalans from *Terminalia chebula* Retz. In southern India the flowers are used as a fast yellow dye for leather. In Gujarat the flower buds are used in the galling process prior to dyeing cotton cloth and chintzes red, pink or purple with madder roots (*Rubia cordifolia* L.). Boiled seeds are an important ingredient in indigo vats, where specific bacterial fermentation ensures the reduction of insoluble indigo into the soluble leuco-indigo, allowing textile fibres to be impregnated by the dye solution. The seeds of *Senna auriculata* serve as a source of sugars to keep the fermentation process going.
Branches are used as chewing sticks and toothbrushes. The bark fibre can be made into rope, and a fermented mixture of pounded bark and dissolved molasses serves as an alcoholic beverage in some parts of India. *Senna auriculata* does not reach a volume adequate for timber, but sometimes handles of small tools are made from the wood. It is used for revegetating erodible soils and as a green manure, and has also proved very effective in reclaiming sodic soils which have been dressed with gypsum. The leaves are sometimes used to make tea, dried flowers serve as a coffee substitute, and in times of food scarcity the young tender pods, young leaves and flowers are eaten as a vegetable. The quantity eaten is critical since *Senna auriculata* is considered not well suited as fodder for goats and cattle because of the poisonous substances in the plant. The stem bark is used in India to stupefy fish. Uses in traditional medicine are numerous. The roots and bark are astringent and are used for gargles, as an alterative, and to cure skin diseases, eye troubles and rheumatism. A decoction of the flowers and the seeds is recommended for diabetes, seeds are used to cure eye diseases, gonorrhoea and gout. In Tanzania the plant is used to treat impotence, which may be related to diabetes. Leaves and fruits serve as an anthelmintic and diuretic. Sometimes *Senna auriculata* is cultivated as an ornamental. A most curious use of *Senna auriculata* is reported from India. It is believed that branches were formerly used in the fabrication of wootz Damascus steel. They were added to the crucible and heated with the ore to obtain the chemical composition that gave the steel its beautiful patterning.

Production and international trade *Senna auriculata* was a major source of tannin in India, the most important areas of production being Madras, Hyderabad and Mysore. In the past, annual production of dried bark in India reached 50,000 t. For local use, dried bark is marketed in bags of 100–120 kg. Syntans and imported barks, especially of black wattle (*Acacia mearnsii* De Wild.) from southern Africa, have largely replaced avaram bark. Outside India, *Senna auriculata* has never been cultivated on a large scale.

Properties The bark of *Senna auriculata* plants over three years old contains 15–24% of tannin on a dry weight basis. The tannin content increases with age, but the increase slows down after the third year. The tannin penetrates the hide quickly. In the dyeing applications, the tannins present in the plant act as vegetable mordants in combination with colorants of other chemical groups, such as anthraquinone glucosides, detected in the leaves.
Saponin and the cardiac glucoside sennapicrin are reported from the roots. The bark, flowers, and seeds contain pyrrolizidine alkaloids, suspected of hepatotoxic properties. However, in experiments with rats, leaf extracts of *Senna auriculata* have been shown to alleviate the effects of liver injury caused by alcohol. Extracts of dried flowers showed significant anti-hyperglycaemic effect in rats, comparable to the therapeutic drug acarbose. This supports the traditional use as a treatment for diabetes.

Description Shrub or small tree up to 7 m tall, with trunk up to 20 cm in diameter; bark



Senna auriculata – 1, *flowering branch;* 2, *fruit.*
Source: PROSEA

thin, brown, lenticellate. Leaves alternate, paripinnately compound; stipules large and leafy, broadly reniform, 7–22 mm wide, persistent; petiole 10–14 cm long; rachis provided with a gland between each pair of leaflets; leaflets 6–13 pairs, oblong-elliptical to obovate-elliptical, 10–35 mm × 5–12 mm, rounded and mucronate at apex, glabrous to pubescent. Inflorescence an axillary raceme, 2–8-flowered. Flowers bisexual, zygomorphic, 5-merous; sepals rounded at apex; petals free, unequal, 1.5–3 cm long, yellow; stamens 10, the 3 lower ones largest and fertile, others usually sterile; ovary superior, falcate, c. 1.5 cm long, stalked, style c. 1 cm long. Fruit a flattened cylindrical pod 5–18 cm × 1–2 cm, transversely undulate between the 10–20 seeds, indehiscent. Seeds compressed ovoid-cylindrical, 7–9 mm × 4–5 mm, with a distinct areole on each face.

Other botanical information Until the early 1980s, *Cassia* was considered to be a very large genus of over 500 species, but then it was split into 3 genera: *Cassia* s.s. with about 30 species, *Senna* with 270 species and *Chamaecrista* with 250 species.

Growth and development Plants reach about 3 m height with 3.5 cm stem diameter in 2 years, in 4 years about 5 m height and 7 cm stem diameter. Flowering and fruiting is almost throughout the year, but in India there are usually two main flowering periods, one in the early monsoon and another in the late monsoon.

Ecology Under natural or naturalized conditions, *Senna auriculata* is found in woodland and wooded grassland up to 600 m altitude. It usually grows wild in dry regions with a minimum annual precipitation of 400 mm, but it also tolerates wet climates with an annual precipitation of up to 4300 mm. The mean annual temperature can vary from 16°C to 27°C. *Senna auriculata* needs full sun. It tolerates many soil types, including saline soils, but prefers fairly rich, well-drained soils.

Propagation and planting *Senna auriculata* can be propagated by seed and stem cuttings. For quick germination seeds are scarified and held in running water. The seedlings are fairly resistant to desiccation. Stem cuttings are planted 5–12.5 cm apart in rows.

Management Thinning is necessary one year after sowing. Weeding and cultivation stimulate growth but are not absolutely necessary. Limed soil is reported to increase the amount of tannin. Coppiced plants regrow well.

Harvesting Starting the third year after establishment, the twig bark of *Senna auriculata* can be stripped and used. Twigs that have not developed a corky bark are best. Coppiced plants can be harvested annually.

Yield The yield of green bark of *Senna auriculata* averages 1500 kg per ha in a 4-year-old plantation of about 9000 plants/ha.

Handling after harvest The bark is sun dried in small pieces and stored or marketed. Unstripped twigs can be directly used by the tanners to make a tanning extract which is as effective as when made from dried stripped bark. To prepare a yellow dye, flowers (about twice the weight of the textile to be dyed) are boiled in water. Then the cloth, previously mordanted with alum, is immersed into the bath, which is kept boiling until the desired shade is obtained. In Andhra Pradesh (India), 2.5 kg of broken and cooked *Senna auriculata* seeds are added to a vat of indigo of approximately 227 l with 750 g of indigo.

Genetic resources *Senna auriculata* is widespread and does not seem to be in danger of genetic erosion. The status of the plants found in natural habitats in Tanzania needs further clarification.

Prospects *Senna auriculata* is easy to grow and has numerous uses. The good tanning properties of the bark, the possibility of using the flowers and leaves as renewable dye sources that can be collected without damaging the tree, and its medicinal properties make it an interesting plant for planting in the drier parts of Africa.

Major references Abesundara, Matsui & Matsumoto, 2004; Brenan, 1967; Burkill, 1995; CSIR, 1950; Duke, 1981; Mohanty, Chandramouli & Naik, 1987; Moshi & Mbwambo, 2002.

Other references de Luynes, 1844; Greenway, 1941; Kumar et al., 2003; Purseglove, 1968; Watt & Breyer-Brandwijk, 1962.

Sources of illustration Maman Rahmansyah, 1991.

Authors P.C.M. Jansen

Based on PROSEA 3: Dye and tannin-producing plants.

SORGHUM BICOLOR (L.) Moench

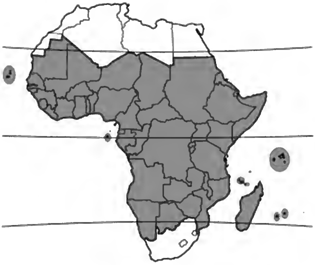
Protologue Methodus: 207 (1794).

Family Poaceae (Gramineae)

Chromosome number $2n = 20$

Vernacular names Sorghum, sorgo, guinea corn, great millet, durra (En). Sorgho, gros mil, sorgho rouge (dye cultivars), sorgho des teinturiers (dye cultivars) (Fr). Sorgo, milho miúdo, massambala (Po). Mtama (Sw).

Origin and geographic distribution The greatest diversity in both cultivated and wild types of *Sorghum* is found in north-eastern tropical Africa. The crop may have been domesticated in that region, possibly Ethiopia. Various hypotheses have been put forward as to when the crop was domesticated, from as early as 5000–3000 BC to around 1000 BC, but the latter period is more widely accepted now. From north-eastern Africa sorghum was distributed all over Africa and along shipping and trade routes through the Middle East to India. From India it is believed to have been carried to China along the silk route and through coastal shipping to South-East Asia. From West Africa sorghum was taken to the Americas through the slave trade. It was introduced into the United States for commercial cultivation from North Africa, South Africa and India at the end of the 19th century. It was subsequently introduced into South America and Australia. It is now widely cultivated in drier areas of Africa, Asia, the Americas, Europe and Australia between latitudes of up to 50°N in North America and Russia and 40°S in Argentina. Sorghum types exclusively cultivated for the dye in the leaf sheaths can be found from Senegal to Sudan.



Sorghum bicolor – planted

Uses Sorghum is an important staple food, particularly in semi-arid tropical regions of Africa and Asia, and an important feed grain and fodder crop in the Americas and Australia. In the simplest food preparations, the whole grain is boiled (to produce a food resembling rice), roasted (usually at the dough stage), or popped (like maize). More often the grain is ground or pounded into flour, often after hulling. Sorghum flour is used to make thick or thin porridge, pancake, dumplings or couscous, opaque and cloudy beers and non-alcoholic fermented beverages. In Africa sorghum grain is germinated, dried and ground to form malt, which is used as a substratum for fermentation in local beer production. White grain is generally preferred for cooking while red and brown grains are normally used for beer making. Where bird pressure is high, e.g. around Lake Victoria, red and brown types rich in tannin may be grown for food instead of white types. In China sorghum is extensively distilled to make a popular spirit and vinegar. Sorghum grain is a significant component of cattle, pig and chicken feeds in the United States, Central and South America, Australia and China, and is becoming important in chicken feed in India. It requires grinding, rolling, flaking or steaming to maximize its nutritional value.

Several non-edible sorghum cultivars are exclusively grown for the red dye present in the leaf sheaths and sometimes also in adjacent stem parts. In Africa this dye is used particularly for goat-skin leather (e.g. in Nigeria), but also for mats, textiles, strips of palm leaves and grasses used in basketry and weaving, ornamental calabashes, wool (e.g. in Sudan), as a body paint and to colour cheese and lick-stones for cattle (e.g. in Benin). A similar dye can be extracted from the grain refuse (glumes and grain wall) of several red sorghum cultivars grown for food or for beer-making. In Nigeria the red sorghum dyes were traditionally used by the Bunu, Aworo, Igbira and Okpella people for a fabric called 'abata', used as a funeral hanging, decorated with patterns made by thick threads added to the weft of the fabric. The fabrics in which the dominant colours were derived from sorghum were known as 'ifala'. Sorghum is also used to provide the violet colours decorating the masks worn during certain dances by Yoruba people in southern Benin and in south-western Nigeria. In Côte d'Ivoire sorghum and other tannin-rich dyes are used in combination with mud to create the patterns of the painted cloths produced in the Korhogo region. The dye was formerly exported to Morocco where it was used in the leather industry. In China sorghum types with red panicles and leaf sheaths were also used for dyeing. In the 19th century red sorghums were exported to Europe where the dye was known as 'carmin de sorgho'. It was extracted by squeezing out the juice, which was then fermented. Used with wool or silk mordanted with tin or chrome, the result was a colourfast red-brown that was once known as 'rouge badois'. 'Durra red', a similar product, was imported from India into the United Kingdom where the dye was known as 'Hansen brown' or 'Meyer brown'. Recently the use of sorghum dye in hair dying products has been patented.

The stems of sweet sorghum types are chewed like sugar cane and, mainly in the United States, a sweet syrup is pressed from them. In North America and eastern Europe special types with very long, fibrous and few-seeded inflorescences, known as 'broomcorn', are grown to make brooms. Sorghum plant residues are used extensively as material for roofing, fencing, weaving and as fuel. The stems can be used for the production of fibre board. Danish scientists have made good panelling using stem chips of sorghum. The stover remaining after harvesting the grain is cut and fed to cattle, sheep and goats, or may be grazed. Some farmers grind harvested stover and mix it with sorghum bran or salt to feed livestock. Sorghum is also grown for forage, either for direct feeding to ruminants or for preservation as hay or silage. Sorghum flour is used to produce an adhesive in the manufacture of plywood. Sweet sorghum is suitable for the production of alcohol, while the bagasse is a suitable source of paper pulp for the production of kraft paper, newsprint and fibre board. Sorghum has various applications in African traditional medicine: seed extracts are drunk to treat hepatitis, and decoctions of twigs with lemon against jaundice; leaves and panicles are included in plant mixtures for decoctions against anaemia. The Salka people in northern Nigeria use sorghum in arrow-poisons. The red pigment is said to have antimicrobial and antifungal properties and is also used as a cure for anaemia in traditional medicine.

Production and international trade Sorghum grain is the fifth most important cereal in the world after wheat, rice, maize and barley. In Africa it comes second after maize in terms of production. According to FAO estimates, the average world production of sorghum grain in 1999–2003 amounted to 57.7 million t/year from 42.6 million ha. The production in sub-Saharan Africa was 19.0 million t/year from 22.8 million ha. The main producing countries are the United States (12.0 million t/year in 1999–2003 from 3.2 million ha), India (7.6 million t/year from 9.8 million ha), Nigeria (7.6 million t/year from 6.9 million ha), Mexico (6.0 million t/year from 1.9 million ha), Sudan (3.4 million t/year from 5.3 million ha), Argentina (3.0 million t/year from 630,000 ha), China (3.0 million t/year from 840,000 ha), Australia (1.9 million t/year from 690,000 ha), Ethiopia (1.4 million t/year from 1.2 million ha) and Burkina Faso (1.3 million t/year from 1.4 million ha). In sub-Saharan Africa annual production increased from around 10 million t from 13 million ha in the early 1960s to about 20 million t from 25 million ha in the early 2000s.

Almost all sorghum traded on international markets is for use as livestock feed. Average world exports of sorghum in 1998–2002 amounted to 6.3 million t/year, almost all from the United States (5.6 million t/year). The main importers are Mexico and Japan. In tropical Africa most sorghum is grown for home consumption (except for beer production). In southern and eastern Africa malting sorghum for beer brewing has developed into a large-scale commercial industry, using about 150,000 t of sorghum grain annually. In Uganda commercial production of lager beer using sorghum instead of barley is becoming a great success (annual requirement of sorghum is 3000 t) and is very promising for other African countries. In Nigeria sorghum malting has become a major industry for lager and stout beer brewing and for malt beverages, using about 15,000 t of sorghum annually. In South Africa an instant breakfast cereal is made from sorghum that is similar in quality but much cheaper than wheat or maize products. Annual production is 12,000 t and is increasing steadily.

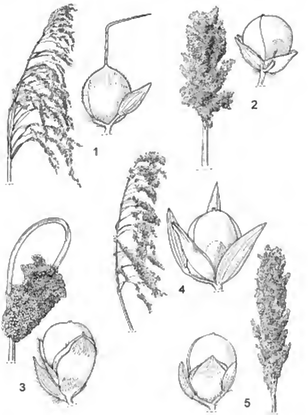
In West Africa small tied bundles of 4–6 leaf sheaths of sorghum dye cultivars are offered for sale on local markets (in the 1990s the price was about 150 CFA). In 1993 in Burkina Faso, the red pigment was successfully extracted chemically from sorghum leaf sheaths and offered for sale as dry powder on the world market.

Properties The composition of sorghum grain per 100 g edible portion is: water 9.2 g, energy 1418 kJ (339 kcal), protein 11.3 g, fat 3.3 g, carbohydrate 74.6 g, Ca 28 mg, P 287 mg, Fe 4.4 mg, vitamin A 0 IU, thiamin 0.24 mg, riboflavin 0.14 mg, niacin 2.9 mg and ascorbic acid 0 mg. The essential amino acid composition per 100 g edible portion is: tryptophan 124 mg, lysine 229 mg, methionine 169 mg, phenylalanine 546 mg, threonine 346 mg, valine 561 mg, leucine 1491 mg and isoleucine 433 mg. The principal fatty acids are per 100 g edible portion: linoleic acid 1305 mg, oleic acid 964 mg and palmitic acid 407 mg (USDA, 2004). Sorghum grain is first limiting in lysine, then in methionine and threonine. Much of the protein in sorghum is prolamine (39–73%), which is poorly digestible. As a result, maximum available protein in sorghum grain is usually 8–9%. The tannin content of sorghum also affects its nutritional value. High- and low-tannin sorghum types are distinguished. High-tannin sorghum types (sometimes called 'brown sorghums', although the grain may also be white, yellow or red) have less nutritional value but have agronomic advantages, including resistance to birds, insects, fungi and decreased sprouting in the panicle. Sorghum types without a pigmented grain wall ('white sorghums') do not contain condensed tannins and have a nutritional value similar to that of maize. Decortication, parboiling, malting or steeping in alkali solutions significantly reduce the tannin content of sorghum grain. In general the endosperm accounts for 82–84% of the grain weight, the germ for 9–10% and the grain wall for 6–8%. The starch granules in the endosperm have a diameter of (4–)15(–25) μm. The starch normally contains 70–80% amylopectin and 20–30% amylose, although some types contain 100% amylopectin and others up to 62% amylose. The gelatinization temperature ranges from 68–75°C. Sorghum grain does not contain gluten and cannot be used for leavened products unless mixed with wheat.

The composition of the green plant varies according to age and cultivar but it normally contains 78–86 g of water per 100 g of fresh material. On a dry basis it contains per 100 g: protein 12 g, carbohydrate 40–50 g and fibre 20–30 g. The glycoside dhurrin occurs in the aerial parts of most sorghum. Dhurrin is hydrolyzed to hydrocyanic acid (HCN), which is highly toxic and can kill grazing animals. It is particularly concentrated in the young leaves and tillers and in plants that are suffering from drought. HCN content usually declines with age, reaching non-toxic levels 45–50 days after planting, and HCN is destroyed when the fodder is made into hay or silage.

The red pigment in sorghum dye cultivars is composed of anthocyanic compounds, particularly rich (95%) in the stable apigeninidin chloride (3-deoxyanthocyanidin) and tannins of the condensed proanthocyanidins group (producing phlobaphen reds). The red pigment in the sorghum leaf sheath makes up to over 20% of the dry weight. The role of the non-pathogenic fungus *Bipolaris maydis* in the production of apigeninidin in these cultivars deserves further research. Used without a mordant, the dye obtained from sorghum gives a dark red that is fairly colourfast and still much used in eastern Africa, particularly Sudan and Ethiopia, for dyeing leather, cotton and the grasses and reeds used for woven matting. Black colours are obtained with natron salt and iron mordants. From red sorghum grain the pigments apigenin, quercimeritrin, kaempferol glucosides, apigenidin glucosides, apigeninidin, luteolinidin and 7-O-methyl-luteolin-glucoside have been isolated. From the stem of red sorghum cultivars the constituents of the red dye were the anthocyanidin apigeninidin (17%) and the flavonoids luteolin (9%) and apigenin (4%). The anaemia curing property of the red pigment has been confirmed in tests with rats.

Description Annual grass up to 5 m tall, with one to many tillers, originating from the base or stem nodes; roots concentrated in the top 90 cm of the soil but sometimes extending to twice that depth, spreading laterally up to 1.5 m; stem (culm) solid, usually erect. Leaves alternate, simple; leaf sheath 15–35 cm long, often with a waxy bloom, with band of short white hairs at base near attachment, reddish in dye cultivars, auricled; ligule short, c. 2 mm long, ciliate on upper free edge; blade lanceolate to linear-lanceolate, 30–135 cm × 1.5–13 cm, initially erect, later curving, margins flat or wavy. Inflorescence a terminal panicle up to 60 cm long; rachis short or long, with primary, secondary and sometimes tertiary branches, with spikelets in pairs and in groups of three at the ends of branches. Spikelet sessile and bisexual or pedicelled and male or sterile, with 2 florets; sessile spikelet 3–10 mm long, with glumes approximately equal in length, lower glume 6–18-veined, usually with a coarse keel-like vein on each side, upper glume usually narrower and more pointed, with central keel for part of its length, lower floret consisting of a lemma only, upper floret bisexual, with lemma cleft at apex, with or without kneed and twisted awn, palea, when present, small and thin, lodicules 2, stamens 3; ovary superior, 1-celled with 2 long styles ending in feathery stigmas; pedicelled spikelet persistent or deciduous, smaller and narrower than sessile spikelet, often consisting of only two glumes, sometimes with lower floret consisting of lemma only and upper floret with lemma, 2 lodicules and 3 stamens. Fruit a caryopsis (grain), usually partially covered by glumes, 4–8 mm in diameter, rounded and bluntly pointed.



Sorghum bicolor – panicles and spikelets of the 5 basic races: 1, bicolor; 2, caudatum; 3, durra; 4, guinea; 5, kafir.
Source: PROSEA

Other botanical information *Sorghum* comprises 20–30 species. *Sorghum bicolor* belongs to section *Sorghum*, together with the 2 perennial species *Sorghum halepense* (L.) Pers. and *Sorghum propinquum* (Kunth) Hitchc. At present, *Sorghum bicolor* is mostly considered as an extremely variable crop-weed complex, comprising wild, weedy and cultivated annual types (classified as subspecies) which are fully interfertile. The cultivated types are classified as subsp. *bicolor* (synonyms: *Sorghum aukolib* Stapf, *Sorghum caudatum* Stapf, *Sorghum cernuum* Host, *Sorghum dochna* (Forssk.) Snowden, *Sorghum durra* (Forssk.) Stapf, *Sorghum membranaceum* Chiov., *Sorghum nigricans* (Ruiz & Pav.) Snowden, *Sorghum subglabrescens* (Steud.) Schweinf. & Asch., *Sorghum vulgare* Pers.) and they are subclassified into different races on the basis of grain shape, glume shape and panicle type. Five basic races and 10–15 hybrid combinations of 2 or more of these races are recognized and grouped into subsp. *bicolor*. A classification into cultivar groups would, however, be more appropriate. The 5 basic races are:

- Bicolor: the most primitive cultivated sorghum, characterized by open inflorescences and long clasping glumes that enclose the usually small grain at maturity. Cultivars are grown in Africa and Asia, some for their sweet stems to make syrup or molasses, others for their bitter grains used to flavour sorghum beer, but they are rarely important. They are frequently found in wet conditions.
- Caudatum: characterized by turtle-backed grains that are flat on one side and curved on the other; the panicle shape is variable and the glumes are usually much shorter than

the grain. Cultivars are widely grown in north-eastern Nigeria, Chad, Sudan and Uganda. The types used for dyeing also belong here and are known as 'karan dafi' by the Hausa people in Nigeria.

- Durra: characterized by compact inflorescences, characteristically flattened sessile spikelets, and creased lower glumes; the grain is often spherical. Cultivars are widely grown along the fringes of the southern Sahara, western Asia and parts of India. The durra type is predominant in Ethiopia and in the Nile valley in Sudan and Egypt. It is the most specialized and highly evolved of all races and many useful genes are found in this type. Durra cultivars range in maturity from long to short-season. Most of them are drought resistant.
- Guinea: characterized by usually large, open inflorescences with branches often pendulous at maturity; the grain is typically flattened and twisted obliquely between long gaping glumes at maturity. Guinea sorghum occurs primarily in West Africa, but it is also grown along the East African rift from Malawi to Swaziland and it has also spread to India and the coastal areas of South-East Asia. Many subgroups can be distinguished, e.g. with cultivars especially adapted to high or low rainfall regimes. In the past the grain was often used as ship's provisions because it stored well.
- Kafir: characterized by relatively compact panicles that are often cylindrical in shape, elliptical sessile spikelets and tightly clasping glumes that are usually much shorter than the grain. Kafir sorghum is an important staple across the eastern and southern savanna from Tanzania to South Africa. Kafir landraces tend to be insensitive to photoperiod and most commercially important male-sterile lines are derived from kafir type sorghum.

Hybrid races exhibit various combinations and intermediate forms of the characteristics of the 5 basic races. Durra-bicolor is found mainly in Ethiopia, Yemen and India, guinea-caudatum is a major sorghum grown in Nigeria and Sudan, and guinea-kafir is grown in East Africa and India. Kafir-caudatum is widely grown in the United States and almost all of the modern North American hybrid grain cultivars are of this type. Guinea-caudatum with yellow endosperm and large seed size is used in breeding programmes in the United States.

The wild representatives are classified as subsp. *verticilliflorum* (Steud.) Piper (synonyms: *Sorghum arundinaceum* (Desv.) Stapf, *Sorghum bicolor* (L.) Moench subsp. *arundinaceum* (Desv.) de Wet & J.R.Harlan): tufted annual or short-lived perennial, with slender to stout culms up to 4 m tall; leaf blade linear-lanceolate, up to 75 cm × 7 cm; panicles usually large, somewhat contracted to loose, up to 60 cm × 25 cm, branches obliquely ascending, spreading or pendulous. Wild types extend across the African savanna and have been introduced into tropical Australia, parts of India and the New World.

The weedy plants are usually considered as hybrids between subsp. *bicolor* and subsp. *verticilliflorum*, and named subsp. *drummondii* (Steud.) de Wet (synonyms: *Sorghum* ×*drummondii* (Steud.) Millsp. & Chase, *Sorghum aterrimum* Stapf, *Sorghum sudanense* (Piper) Stapf); they occur in Africa wherever cultivated sorghum and its wild relatives are sympatric because they cross freely. These weedy plants occur in recently abandoned fields and field margins as a very persistent weed; stem up to 4 m tall; leaf blade lanceolate, up to 50 cm × 6 cm; panicle usually rather contracted, up to 30 cm × 15 cm, often with pendulous branches. A well-known forage grass, 'Sudan grass', belongs to this complex.

Growth and development The optimum temperature for sorghum seed germination is 27–35°C. Seedling emergence takes 3–10 days. Panicle initiation takes place after approximately one third of the growth cycle. By this stage the total number of leaves (7–24) has been determined and about one-third of total leaf area has developed. Rapid leaf development, stem elongation and internode expansion follow panicle initiation. Rapid growth of the panicle also occurs. By the time the flag leaf is visible, all but the final 3 to 4 leaves are fully expanded and light interception is approaching its maximum; lower leaves have begun to senesce. During the boot stage, the developing panicle has almost reached its full size and is clearly visible in the leaf sheath; leaf expansion is complete. The peduncle grows rapidly and the panicle emerges from the leaf sheath. Flowering follows soon after panicle emergence, with the interval largely determined by temperature. Individual panicles start flowering from the tip downwards and flowering may extend over 4–9 days. Sorghum is predominantly self-pollinating; cross-pollination may range from 0–50%, but is on average about 5–6%. Grain filling occurs rapidly between flowering and the soft dough stage, with about half the total dry weight accumulating in this period. Lower leaves continue to senesce and die. By the hard dough stage, grain dry weight has reached about three-quarters of its final level. At physiological maturity, determined by the appearance of a dark layer at the hilum (where the grain is attached to the panicle), maximum dry weight has been achieved. Moisture content of the grain is usually between 25–35% at this stage. The time taken between flowering and maturity depends on environmental conditions but normally represents about one-third of the duration of the crop cycle. Further drying of the grain takes place between physiological maturity and harvest, which usually occurs when grain moisture content has fallen below 20%. Leaves may senesce rapidly or stay green with further growth if conditions are favourable. Early maturing sorghum cultivars take only 100 days or less, whereas long-duration sorghum requires 5–7 months. Sorghum follows the C_4-cycle photosynthetic pathway.

Ecology Sorghum is primarily a plant of hot, semi-arid tropical environments that are too dry for maize. It is particularly adapted to drought due to a number of morphological and physiological characteristics, including an extensive root system, waxy bloom on leaves that reduces water loss, and the ability to stop growth in periods of drought and resume it when the stress is relieved. A rainfall of 500–800 mm evenly distributed over the cropping season is normally adequate for cultivars maturing in 3–4 months. Sorghum tolerates waterlogging and can also be grown in areas of high rainfall. It tolerates a wide range of temperatures and is also grown widely in temperate regions and at altitudes up to 2300 m in the tropics. The optimum temperature is 25–31°C, but temperatures as low as 21°C will not dramatically affect growth and yield. Sterility can occur when night temperatures fall below 12–15°C during the flowering period. Sorghum is susceptible to frost, but to a lesser extent than maize and light night-frosts during ripening cause little damage. Sorghum is a short-day plant with a wide range of reactions to photoperiod. Some tropical cultivars fail to flower or to set seed at high latitudes. In the United States, Australia and India the existence of mild photoperiod-sensitive to virtually insensitive cultivars has been recorded.

Sorghum is well suited to grow on heavy Vertisols commonly found in the tropics, where its tolerance of waterlogging is often required, but is equally suited to light sandy soils. The best growth is achieved on loams and sandy loams. Sorghum tolerates a range of soil pH from 5.0–8.5 and is more tolerant of salinity than maize. It is adapted to poor soils and can produce grain on soils where many other crops would fail.

In the floodplains of the Senegal and Niger rivers and in parts of Chad and Cameroon sorghum is sown in the early dry season when the water recedes, and the crop survives on residual moisture ('culture de décrue').

Propagation and planting Sorghum is normally grown from seed. The 1000-grain weight is 13–40 g. Seed dormancy is not common in cultivated sorghum. A fine seedbed is preferable but is often not achieved. The seed is usually sown directly into a furrow following a plough, but can also be broadcast and harrowed into the soil. Optimum plant spacing depends on soil type and availability of moisture. In low-rainfall areas a population of 20,000 plants/ha is normal, in high-rainfall areas 60,000 plants/ha. For favourable conditions, spacings of 45–75 cm between rows and 15–25 cm within the row, resulting in 80,000–180,000 pockets per ha, are normal; for drier or less fertile conditions rows 1 m apart, or broadcasting at 6 kg seed per ha. A planting depth of 2.5–5 cm is common, and up to 25 seeds may be sown per pocket. Occasionally, seedlings are grown in a nursery and transplanted into the field early in the dry season, e.g. on the floodplains round Lake Chad in Africa ('sorgho repiqué'). Sweet sorghum in the United States is also sometimes transplanted. Sorghum can also be propagated vegetatively by splitting tillers from established plants and transplanting them, a practice that is often used by small farmers to fill gaps. Sorghum may be harvested more than once as a ratoon crop, e.g. in locations with a bimodal rainfall pattern. Sorghum is often grown in intercropping systems with maize, pearl millet, cowpea, common bean, groundnut and bambara groundnut; in India also with pigeonpea.

Dye cultivars are never grown in large quantities. Farmers usually grow a few plants in or around their normal sorghum field or near the house.

Management Sorghum does not compete well with weeds during the early stages of growth, and it is recommended that weeding be done early during the seedling stage. In tropical Africa weeding is commonly done once or twice with a hoe but sometimes animal-drawn or tractor-drawn cultivators are used. Where couch grass (*Cynodon dactylon* (L.) Pers.) is a problem more frequent weeding is necessary. Sorghum may be weeded by a combination of inter-row cultivation with animal-drawn implements and hand weeding within rows. Chemical weed control is almost non-existent among small farmers. Thinning can be carried out at the same time as hand weeding, or at intervals during the crop cycle, particularly where thinnings are used to feed livestock. Subsistence farmers rarely apply fertilizer, but application of farmyard manure or ash is common. In South Africa and the United States high doses of fertilizers are used in the production of sorghum. In tropical Africa sorghum is grown mainly as a rainfed crop, but it is grown under irrigation in Sudan. It is grown in rotations with maize, pearl millet, finger millet, cotton and other crops. It is often planted late in the rotation, as it tolerates low soil fertility. Under certain conditions decomposing roots of sorghum have an allelopathic effect on the subsequent crop, including sorghum.

Diseases and pests Common seed and seedling rot diseases in sorghum are caused by soil- and seed-borne *Aspergillus*, *Fusarium*, *Pythium*, *Rhizoctonia* and *Rhizopus* spp. They are controlled by treatment of the seed with fungicides. Anthracnose (*Colletotrichum graminicola*) is common in hot and humid parts of Africa. Control measures include the use of resistant cultivars and crop rotation. Downy mildew (*Peronosclerospora sorghi*) may cause serious yield losses; the use of resistant cultivars and seed treatment are recommended. Smuts (*Sporisorium* spp.) are important panicle diseases. Loose and covered kernel smut are controlled by seed treatment with fungicides; head smut and long smut by using resistant cultivars and cultural practices such as crop rotation and removal of infected panicles. Grain mould is caused by a complex of fungal pathogens (predominantly *Cochliobolus lunatus* (synonym: *Curvularia lunata*), *Fusarium* spp. and *Phoma sorghina*) that infect the grain during development and can lead to severe discoloration and loss of quality. It is most severe in seasons when rains continue through the grain maturity stage and delay the harvest. Control measures include adjustment of the sowing date to avoid maturation during wet weather, and the use of resistant cultivars.

Important pests of sorghum in tropical Africa are shoot fly (*Atherigona soccata*) and stem borers (particularly *Busseola fusca*, *Chilo partellus* and *Sesamia calamistis*). Shoot fly larvae attack shoots of seedlings and tillers, and cause 'dead hearts'. Stem borers cause damage in all crop stages. Damage by both shoot fly and stem borers can be reduced by early, non-staggered planting and seed or soil treatment with insecticides. Resistance to shoot fly is associated with low yield. Foliage pests include army worms (*Spodoptera* and *Mythimna* spp.); they are controlled by contact insecticides. Larvae of the sorghum midge (*Stenodiplosis sorghicola*, synonym: *Contarinia sorghicola*) feed on the young grains in the panicle. Damage can be limited by sowing early-maturing cultivars and avoiding staggered planting. Head bugs (*Eurystylus* and *Calocoris* spp.) suck on developing grains, resulting in yield loss, grain deformation and discoloration and infection by moulds. Guinea type sorghum is generally less affected. In practice, control methods of diseases and pests are mainly preventative or cultural, including selection of optimum planting dates, seed treatment and crop rotation. Early sowing is particularly important as a mechanism to avoid large insect populations at times when plants are most susceptible to damage. High levels of host plant resistance are available for sorghum midge, but only low levels of resistance for the other pests. Chemical control of diseases and insect pests is rarely practised in tropical Africa.

Birds, especially *Quelea quelea*, cause important yield losses. Control measures include the choice of suitable planting dates, timely harvesting, bird scaring and the destruction of roosting and nesting sites. Brown sorghum is less preferred by birds than the tannin-free white sorghum.

Sorghum is very susceptible to damage by storage pests, the main ones being rice weevil (*Sitophilus oryzae*), flour beetle (*Tribolium castaneum*) and the grain moth (*Sitotroga cerealella*). Damage can be minimized by drying grain adequately before storage. Cultivars with hard grain also suffer less damage.

The parasitic weed *Striga* (especially *Striga hermonthica* (Del.) Benth., but also *Striga asiatica* (L.) Kuntze, *Striga densiflora* Benth. and *Striga forbesii* Benth.) has become a major constraint to sorghum cultivation, particularly in Africa, where severe infestations can lead to grain losses of 100% and land being abandoned. *Striga* can be controlled by cultural methods such as rotation with trap crops or with crops that are not susceptible (e.g. groundnut, cotton or sunflower), rigorous removal of the weeds before flowering and application of nitrogen fertilizer and herbicides. A few sorghum cultivars that are resistant or tolerant to *Striga* have been identified.

Harvesting Sorghum is usually harvested when the grain moisture content has fallen below 20%, and the grain has become hard. Harvesting is done by hand using a knife to cut the panicles, which are temporarily stored in sacks before being taken to the threshing floor for further drying to a moisture content of 12–13%. Alternatively, the whole plant is cut or pulled up and the panicle removed later. Combine harvesting is possible, but many small farmers cannot afford to buy the machinery. In South Africa combine harvesting is more common.

For dye production, leaf sheaths are harvested when the plant comes to maturity, about 4–6 months after sowing. They can be used immediately or dried and stored.

Rainfed forage sorghum is usually cut only once, soon after flowering. Forage sorghum crops grown under more favourable conditions, often with irrigation and high levels of fertilizer, can be harvested and then left to regrow (ratoon).

Broomcorn is harvested by hand as mechanical harvesters are not available. Sweet sorghum is harvested when the seed is in the soft dough stage when the sugar content of the stalk is highest.

Yield Average sorghum grain yields on farmers' fields in Africa are as low as 0.5–0.9 t/ha because sorghum is often grown in marginal areas under traditional farming practices (low inputs, traditional landraces). Under favourable conditions sorghum can produce grain yields up to 13 t/ha. In South Africa, with intensive agricultural practices and improved cultivars, average commercial yield was 2.3 t/ha in 2001. In China, where sorghum is grown with high levels of inputs, yield averages 3.6 t/ha and in the United States 3.8 t/ha.

Forage yields from single-cut cultivars and hybrids can reach 20 t/ha of dry matter. Multi-cut cultivars and hybrids usually give only slightly higher total yields but produce better quality forage. Sweet sorghum yields about 1000 l syrup per ha in the United States. Average broomcorn yields are 300–600 kg/ha, enough to make 350–800 brooms.

Handling after harvest The harvested grain of sorghum is usually sun-dried, often in the panicle. Panicles, particularly those to be retained for seed, may be stored hanging from the ceiling of kitchens over cooking fires where the smoke helps to deter insect attack. Alternatively, the heads may be threshed after drying and the grain stored in granaries, above or below ground, designed to prevent insect attack.

Traditional food preparation of sorghum is quite varied. The whole grain may be ground into flour or decorticated before grinding to either a fine particle product or flour which is then used in various food products. To prepare porridge, water is boiled and sorghum flour is gradually added until the desired consistency of the paste is reached. Regular stirring is needed to mix the contents thoroughly. Another simple form of sorghum food preparation is to boil the grain before or after decorticating. To make beer, sorghum grain is germinated, dried, pounded into flour and mixed with water and left to ferment in a warm place for some days. To make the non-fermented drink 'mageu' in Botswana and South Africa, milled sorghum malt is mixed with water and kept at room temperature for 2–3 days. Occasional stirring may be necessary.

In a traditional method of dyeing hides with sorghum dye in West Africa, a watery extract of wood ashes, preferably from the wood of *Anogeissus leiocarpa* (DC.) Guill. & Perr., is prepared and allowed to stand for 3–4 hours. The major active compound of the lye is potassium- or sodium carbonate. The red leaf sheaths are pulverized and placed in a large vessel in which the dyeing is carried out. From time to time a little lye is added and diluted with plain water as desired, obtaining a crimson liquid. The tanned hide that has been dressed with oil is folded with the tanned side outwards, the hide is immersed for about two minutes in the dye bath, wrung out and shaken. Alternatively, the dye liquid is painted on the tanned surface with the fingers or a brush. The hide is then rinsed in cold water acidulated with lime juice or tamarind pulp. After the hide has been dried, the process is completed by rubbing the hide with a smooth stone on a wooden block. It is estimated that 1.25 l of dye bath is sufficient for about 6 skins of medium size. Another recipe uses about 30 leaf-sheaths of sorghum, about half a spoonful of soda, a handful of 'sant' pods (*Acacia nilotica* (L.) Willd. ex Delile) or 2 handfuls of chips of mangrove bark, 2 spoonfuls of palm oil and 1.5 l of water. These are all mixed together and boiled, the juice of 5 or 6 limes added, and the liquid is left to simmer for 2 hours. It is then ready for application on the skin by brushing or rubbing.

To obtain a dye of constant high quality, a laboratory extraction technique has been designed in Burkina Faso. Sorghum leaf sheaths are crushed into fine particles, a solvent is added in an acid or basic medium (both give similar results) and a red liquid is produced. By addition of an acid the dyestuff is precipitated and is centrifuged off. The end product is a fine, burgundy-red powder with an apigeninidin concentration of 50–60%, ready for use as a dye. Pure apigeninidin can be obtained by further processing of the powder.

Forage sorghum can be fed to livestock while still green or can be stored in various ways for later use. The forage is often dried and stacked or can be made into silage. Stover left after harvest of grain is often grazed by animals.

Genetic resources A major collection of sorghum germplasm is maintained and distributed to interested researchers by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. The collection extends to over 36,000 accessions from all the major sorghum-growing regions of the world (90 countries). Large germplasm collections of sorghum are also held in the United States (Southern Regional Plant Introduction Station, Griffin, Georgia, 30,100 accessions; National Seed Storage Laboratory, Fort Collins, Colorado, 10,500 accessions) and China (Institute of Crop Germplasm Resources (CAAS), Beijing, 15,300 accessions). In tropical Africa large germplasm collections of sorghum are held in Zimbabwe (SADC/ICRISAT Sorghum and Millet Improvement Program, Matopos, 12,340 accessions), Ethiopia (Institute of Biodiversity Conservation (IBC), Addis Ababa, 7260 accessions), Kenya (National Genebank of Kenya, Crop Plant Genetic Resources Centre, KARI, Kikuyu, 3410 accessions) and Uganda (Serere Agricultural and Animal Production Research Institute, Serere, 2635 accessions).

Breeding The main objectives in sorghum breeding include high grain yield, white grain for human consumption with improved nutritional value and processing quality, and red or brown grain for feed purposes and brewing. In many countries the emphasis is on producing cultivars which combine high grain yield with high stover yields because of the importance of the residues as animal feed. Incorporation of resistance to major yield-limiting diseases and pests, and tolerance of abiotic stresses are also of high priority. Resistance to grain moulds and other diseases as well as to insect pests such as head bugs and sorghum midge has been identified. High-yielding improved cultivars of sorghum are available in most of the main producing countries. These include cultivars and hybrids produced using cytoplasmic male sterility. Compared to traditional landraces they have a weak photoperiodic response and they are less hardy, less tall, with a lower grain quality but a higher yield potential. *Striga*-resistant cultivars have been released in Africa and India, e.g. 'Framida' in Ghana and Burkina Faso. Cultivars resistant to grain mould have also been released. Special cultivars with high biomass production and good forage quality are bred for animal feed. Modern sorghum cultivars predominate in the Americas, China and Australia, but in Africa they occupy probably less than 10% of the area under sorghum. In India about 50% of the sorghum area is sown to modern cultivars and 50% to traditional landraces.

The sorghum genome is relatively small (about 760 Mbp) compared to that of maize (about 2500 Mbp), and construction of a physical genome map is in progress. Several genetic linkage maps have been developed, mainly based on RFLP markers. Various genes have been tagged, e.g. genes associated with head smut resistance, leaf blight resistance and shattering. Many QTLs have been mapped, including those associated with plant height, tillering, seed size, drought resistance and rust resistance. In-vitro plant regeneration has been achieved from calli derived from young leaf bases, shoot apices, immature inflorescences and immature embryos. Protocols have been developed for the production of stably transformed sorghum plants using microprojectile bombardment or *Agrobacterium*-mediated transformation, but the efficiency is generally low, especially with the former technique.

Prospects Sorghum is a hardy, drought-tolerant crop with a high potential yield, which plays an important role in tropical Africa and elsewhere, especially as source of food and fodder, but also for a range of other uses, including as a source of dye. Sorghum has lost part of its traditional area in tropical Africa to maize, which yields better in more favourable environments, is less liable to bird damage and easier to process. It is to be expected, however, that sorghum will remain an important food security crop in less favourable environments in tropical Africa. Important problems in sorghum cultivation to be addressed by research and breeding activities are the large yield losses caused by parasitic weeds (especially *Striga hermonthica*), anthracnose, downy mildew, grain moulds, sorghum midge and stem borers. Improved sorghum cultivars are not widely grown in tropical Africa, and the improvement of seed supply systems should accompany sorghum improvement programmes in this region. Demand for sorghum for non-traditional uses is likely to increase. In particular, the use of sorghum as a feed grain, already well established in many industrialized countries, is likely to become more common in developing countries. However, sorghum faces strong competition from maize in the international feed grain market. Similarly, as increased affluence results in increased demand for meat and dairy products, the use of sorghum as a forage crop in intensive production systems in many tropical regions is likely to expand. The use of sorghum as a raw material for industrial processes will also increase. Research should focus on innovations that are likely to reduce the costs of production of sorghum. This should include research to increase yield levels of available cultivars, and to improve agronomic practices. Emphasis should be placed on enhancing resistance to the main biotic and abiotic stresses and on production of cultivars richer in high quality proteins.

Sorghum dye may profit from the trend of increasing use of natural colourants in foods and cosmetics. Rising harvesting costs of broomcorn in North America and Europe may offer possibilities for expanding this commodity in Africa.

Major references Chantereau et al., 1997; de Vries & Toenniessen, 2001; de Wet, 1978; Doggett, 1988; Murty & Renard, 2001; Rooney & Serna-Saldivar, 2000; Smith & Frederiksen, 2000; Stenhouse & Tippayaruk, 1996; Stenhouse et al., 1997; Taylor, 2003.

Other references Balole, 2001; Bellemare, 1993; Burkill, 1994; Byth (Editor), 1993; Dalziel, 1926; Gao et al., 2005; Harlan & de Wet, 1972; Kouda-Bonafos et al., 1994; Ministry of Agriculture and Rural Development, 2002; National Research Council, 1996; Neuwinger, 2000; Ogwumike, 2002; Pale et al., 1997; Phillips, 1995; Reddy, Ramesh & Reddy, 2004; Rey et al., 1993; Sanders, Ahmed & Nell, 2000; Seshu Reddy, 1991; USDA, 2004b; Westphal, 1981.

Sources of illustration Stenhouse & Tippayaruk, 1996.

Authors T.V. Balole & G.M. Legwaila

Based on PROSEA 10: Cereals.

STRIGA GESNERIOIDES (Willd.) Vatke

Protologue Österr. Bot. Zeitschr. 25: 11 (1875).

Family Scrophulariaceae (APG: Orobanchaceae)

Chromosome number $n = 20$

Synonyms *Striga orobanchoides* (R.Br.) Benth. (1836).

Vernacular names Witchweed, cowpea witchweed (En). Striga (Fr). Kichawi nke (Sw).

Origin and geographic distribution *Striga gesnerioides* is widespread all over tropical Africa, the Indian Ocean islands and tropical Asia. It has been introduced to Florida.

Uses The sap of *Striga gesnerioides* is used to dye skins blue-black in Mali. In Kenya root sap is used to colour the fingers an indigo blue. The flowers yield a pink colour which can be used for painting. As fodder *Striga gesnerioides* is useless; cattle will not graze it and only camels browse it reluctantly when nothing else is available. In Botswana the stem is said to be used as toothbrush. In traditional medicine, the powdered plant is sprinkled on wounds or, made into a paste with some fat, applied against swollen neck glands.

Properties The dyeing properties may derive, as does the cytotoxicity of the plant, from the presence of iridoid glucosides, which have been isolated and characterized from other *Striga* species. An ethanolic extract of whole *Striga gesnerioides* plants showed antifertility effects in male rats. Ethanolic and water extracts showed antihistaminic and mast cell stabilizing activity in rats. The flavones apigenin and luteolin, isolated from *Striga gesnerioides*, showed anti-inflammatory and antispasmodic activities.

Botany Succulent, greenish yellow annual herb up to 35 cm tall, usually branching from the base, glabrous or minutely puberulent; each plant with a single, large, tuberous primary haustorium 1–3 cm in diameter, and with numerous adventitious roots emerging from subterranean scales; stem square but obtusely angled. Leaves opposite, appressed to the stem, scale-like, 5–10 mm × 2–3 mm. Inflorescence a terminal bracteate spike. Flowers bisexual, zygomorphic, 5-merous, not fragrant, sessile; calyx tubular with 5 teeth at apex, 4–6 mm × 2 mm; corolla tubular, 2-lipped, up to 15 mm long, bent in upper part of tube, pale blue to dark purple, upper lobes 2, fused, sharply recurved, up to 2.5 mm long, lower lobes 3, spreading, c. 3 mm long; stamens 4, 2 longer and 2 shorter; ovary superior, tubular, 2-celled, style terete, stigma 2-fid. Fruit an ovoid capsule 1–2 mm × 3 mm, many-seeded. Seeds very small, dust-like, with prominent encircling ridges.

Striga comprises about 40 species in the tropics and subtropics of the Old World with occasional introductions elsewhere. At least 11 *Striga* species attack crops, including all the important tropical cereals (maize, sorghum, pearl millet, finger millet, upland rice), sugar cane and many grasses grown for fodder. Currently 4 species are considered major problems in tropical agriculture: *Striga hermonthica* (Del.) Benth. in cereals, *Striga asiatica* (L.) Kuntze in cereals, *Striga gesnerioides* in a variety of dicots (e.g. cowpea) and *Striga aspera* (Willd.) Benth. in cereals and grasses and they are all widespread in tropical Africa. Most *Striga* species are used in traditional medicine, and occasionally for dyeing; for example *Striga asiatica* is used as a mordant for *Cochlospermum tinctorium* Perr. ex A.Rich., *Striga aspera* is used in Nigeria as a black facial stain, and *Striga hermonthica* is used as a dye itself, but also as a mordant in indigo dyeing to deepen the colour.

Striga gesnerioides is an obligate root parasite with low photosynthetic activity. Its seeds germinate in response to specific germination stimulants exuded by host roots. After germination, an haustorium is formed in the root of the host plant through differentiation of the root apex. A vascular connection is subsequently established between the 2 plants, allowing the parasite to absorb water and nutrients that are essential for its development. Control of the parasite is difficult to achieve because of the intimate association between the parasitic weed and its host. *Striga gesnerioides* as a whole has a very broad host range. It is a major pest in cowpea, parasitizing the roots and often considerably reducing its growth and yield. In the wild it parasitizes leguminous weeds, particularly *Tephrosia* and *Indigofera* in West Africa, but also *Convolvulaceae* (e.g. in Sudan *Merremia*, *Ipomoea* and *Jacquemontia*) and *Euphorbiaceae*. Due to its autogamous nature, many different strains have evolved that can attack few or only a single plant species. These strains vary in their morphology and their distribution often overlaps. In West Africa there are at least five different strains that parasitize cowpea and each one varies in the number of cultivars it can attack. Tobacco and sweet potato are occasionally attacked. Strains attacking tobacco in Zimbabwe do not affect cowpea. Bambara groundnut is not affected; evidence of the occurrence of *Striga gesnerioides* on groundnut is conflicting. The cultivation of crops such as cowpea in monoculture and without fallow years or rotation crops results in a rapid increase of favourable circumstances for growth of *Striga* which, on poor soils, can reduce yield by more than 50%.

Ecology *Striga gesnerioides* is found in open grassland, savanna with scattered trees, on rocky hills and most abundantly as a weed in crops.

Genetic resources and breeding As a widespread parasitic weed *Striga gesnerioides* is not liable to genetic erosion, and breeding research is directed to resistant host plants. *Striga gesnerioides* is very variable and comprises many morphologically identical strains, but as each one is adapted to specific cowpea cultivars, control is very difficult and research complicated. Much research is being done however, and promising results have been obtained towards breeding resistant cowpea cultivars, developing chemicals which force *Striga* seed to germinate, or prevent it from doing so, and developing biological control methods, e.g. through insects feeding on *Striga* (e.g. butterfly larvae of *Junonia orithya* feed on stems and fruits, the weevil larvae of *Smicronyx umbrinus* on fruits).

Prospects *Striga gesnerioides* as source of a dye will remain of minor importance. All research effort is focused on controlling its damage to crops. Promising results have been obtained in developing biological control methods.

Major references Burkill, 2000; Mohamed, Musselman & Riches, 2001; Musselman & Hepper, 1986; Parker & Riches, 1993; Philcox, 1990.

Other references Carsky et al., 2003; Harish, Nagur & Badami, 2001; Hiremath et al., 2000; Hiremath et al., 1997; Irvine, 2000; Neuwinger, 2000; Noorma Wati Haron, 2003; Rank et al., 2004; Raynal, 1993; Reiss, 1996.

Authors P.C.M. Jansen

SYZYGIUM ROWLANDII Sprague

Protologue Bull. Herb. Boissier, sér. 2, 5: 1170 (1905).

Family Myrtaceae

Synonyms *Syzygium abidjanense* Aubrév. & Pellegr. (1936).

Origin and geographic distribution *Syzy-*

gium rowlandii is found from Sierra Leone east to Central African Republic and DR Congo.

Uses A decoction of dried bark of *Syzygium rowlandii* mixed with lime juice yields a black dye, which is used in Sierra Leone for colouring cloth. The wood is strong, hard and durable in water and is used in Liberia for boat keels. Powdered bark, mixed with clay and spices is rubbed on the body to treat rheumatic pains. An infusion of the bark is used in DR Congo against cough, asthma, throat trouble, intercostal pain, food poisoning, stomach pain, diarrhoea and dysentery, often accompanied by massage of the affected part with pulped leaves. Leaf sap and a bark decoction are used in washing to kill parasites and to cure scabies, but are also drunk as a tonic. The powdered root is put on teeth against toothache.

Properties *Syzygium rowlandii* contains tannins and a considerable amount of terpenes.

Botany Shrub or small to medium-sized tree up to 20 m tall; twigs often square and slightly winged, glabrous. Leaves opposite, simple and entire; stipules absent; petiole 7–13 mm long; blade elliptical-obovate to oblong-obovate, 4–25 cm × 1.5–9 cm, base cuneate, apex rounded to long-acuminate, thinly leathery, dotted with small oil glands, lateral veins in 15–28 pairs and prominent on both sides. Inflorescence a terminal or axillary cyme near the apex of branches. Flowers bisexual, regular, 4–5-merous, 5–6 mm in diameter; calyx with triangular lobes up to 1 mm × 2 mm; petals 2–3 mm in diameter, white; stamens numerous, filaments 4–5 mm long; ovary inferior, 2-celled, style 5–7 mm long. Fruit an ellipsoidal to globose berry 10–20 mm × 7–16 mm.

Syzygium is a large genus of about 1000 species, confined to the Old World tropics. In the past it was included in *Eugenia*, which now mainly comprises species from the New World. In DR Congo *Syzygium rowlandii* usually has smaller flowers compared to specimens from West Africa. *Syzygium rowlandii* much resembles *Syzygium guineense* (Willd.) DC., a very variable timber species which usually has smaller flowers. The latter has edible fruits and its bark is used for tanning in Ghana. In Madagascar, *Syzygium jambos* (L.) Alston and *Syzygium cumini* (L.) Skeels are used to dye raffia red-brown, or black with an application of iron-rich mud as mordant, but these species are much more important for their edible fruits. In the south of DR Congo, the Mongo people use the crushed fruit of *Syzygium elegans* Vermoesen. as blue dye for skins and textiles.

Ecology *Syzygium rowlandii* is found in forests, often near water and in swamp forest, usually at 500–2000 m altitude; in the Bahuzi-Biéga montane forest in eastern DR Congo it is characteristic of montane rainforest above 2300 m altitude.

Genetic resources and breeding *Syzygium rowlandii* is widespread and not in danger of genetic erosion.

Prospects *Syzygium rowlandii* as a source of a dye will remain only locally of some importance. The chemical composition of the bark, characteristics of the wood and medicinal properties need further investigation to make evaluation possible.

Major references Burkill, 1997; Irvine, 1961.

Other references Abbiw, 1990; Boutique, 1968; Decary, 1946; Hulstaert, 1966; Kanyamibwa, 1999; Keay, 1954c.

Authors P.C.M. Jansen

TAGETES ERECTA L.

Protologue Sp. pl. 2: 887 (1753).

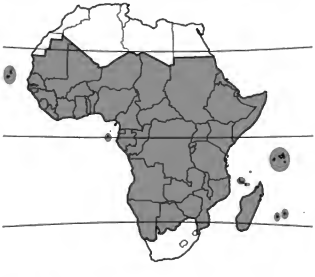
Family Asteraceae (Compositae)

Chromosome number $2n = 24$, 48

Synonyms *Tagetes patula* L. (1753), *Tagetes remotiflora* Kunze (1847).

Vernacular names Aztec marigold, American marigold, African marigold (En). Rose d'Inde, tagète rose d'Inde (Fr). Rosa de oiro, cravo de defuntos, cravo da Índia, cravo de Tunes (Po). Tururu (Sw).

Origin and geographic distribution *Tagetes erecta* is indigenous to Mexico and Guatemala and most probably naturalized in the rest of



Tagetes erecta – planted

Central America and the western Andes of South America. It became naturalized also elsewhere in the tropics and is widely cultivated all over the world (including Africa and the Indian Ocean islands) as a popular garden ornamental. It is cultivated commercially for its dye mainly in Latin America; in Africa on a small scale in Zambia and South Africa.

Uses The yellow flowers of *Tagetes erecta* are the source of two food-colorant products: 'marigold meal' and 'marigold extract'. Marigold meal consists of dried powdered flowers and is used mainly in poultry feed to enhance the yellow colour of the meat and of the egg-yolks. It is used similarly in feed for salmon and crustaceans. Marigold extract is a solvent extract of the flowers, used mainly in western Europe as a yellow to orange food colorant, e.g. in salad dressings, ice cream, dairy products and other foodstuffs with a high fat content, but also in soft drinks, bakery products, jams and confectionery. Fresh and dry flowers can be used to dye wool, silk and cellulose fibres into shades of golden-yellow to orange and olive-green to bronze, depending on the mordanting substances used.

Tagetes erecta is popular worldwide as an ornamental, in Central America particularly in cemeteries. In Honduras, a water extract of the plants was formerly used to wash corpses because of the strong fragrance of the essential oil. Hence the Spanish common name for *Tagetes erecta* used throughout Mexico and Central America 'flor de muerto', flower of the dead. The Portuguese name 'cravo de defuntos', carnation of the dead, has the same origin. The whole herb is considered medicinal with anthelmintic, aromatic, digestive, diuretic, sedative and stomachic properties. It is used internally to treat indigestion, colic, severe constipation, dysentery, cough and fever, and externally to treat sores, ulcers, eczema, sore eyes and rheumatism. In East Africa its roots are eaten with oysternut (*Telfairia pedata* (Sm. ex Sims) Hook.) to relieve pain in the sexual organs. In Mauritius a decoction of the flowers is drunk against jaundice. Secretions from the roots have insecticidal and nematicidal effects. Sometimes *Tagetes erecta* is planted in crop fields as an insect repellent because of its sharp peculiar smell, although the plant itself is susceptible to insect pests. In India it is grown for its essential oil from which an 'attar' is produced. The oil is used in small traces in perfumery to impart floral and 'apple' notes. In Gabon the leaves are occasionally used as a condiment.

Production and international trade The major producers of *Tagetes erecta* are Mexico, Peru, Ecuador, Argentina and Venezuela; minor producers are India, South Africa and Zambia. Statistics on production and international trade are scarce and unreliable. Annual trade in marigold meal is many thousands of tonnes, particularly between countries in Latin America (e.g. Mexico is a large producer and importer). Peruvian export of marigold meal reached 3,000 t in the mid-to-late 1980s. Major importers of marigold meal and its extracts outside Latin America are North America and Western Europe (particularly Spain and Portugal).

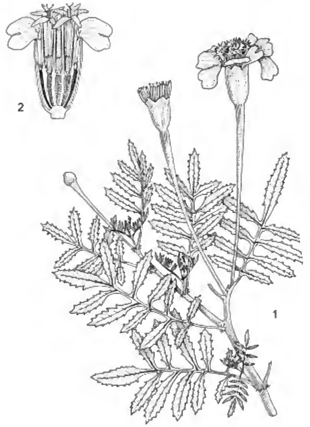
Properties Quantitatively, the colorants in *Tagetes erecta* flowers are mainly quercetagitrin and tagetiin, two glycosides of the flavonoid quercetagetin, giving strong, beautiful dyes for textiles, but with relatively poor light fastness. Currently most important from an economic point of view are the carotenoid components of the flowers, among which lutein (xanthophyll) amounts to 64% and sometimes up to 80%, with smaller amounts of antheraxanthin, zeaxanthin, cryptoxanthin, β-carotene and about 14 other carotenoids. Colorants from marigold are available in a variety of forms. Formulations for animal feeds usually consist of ground dried flowers, oleoresins, or saponified oleoresins. Food colorants are available e.g. as purified lutein esters in oil-soluble or water-dispersible systems, spray-dried emulsions, gum-based emulsions and emulsifier-based emulsions. They show good stability to heat, light, pH changes and sulphur dioxide. They are susceptible to oxidation, which can be minimized through encapsulation or the addition of antioxidants such as ethoxyquin, ascorbic acid, tocopherols or butylated hydroxyanisole and butylated hydroxytoluene. In the United States marigold meal and its extracts are approved only as colorants in poultry feed, but not in human foods (they have not been given FDA-GRAS status). However, admission rules for the use of tagetes extract as oil in foods for direct human consumption are currently being widened. Naturally derived lutein is classified as E161b in the European Union, but marigold extract has not been assigned an E number and is traded as 'vegetable extract'. In the Colour Index it is listed under CI 75135. Lutein is thought to be an essential micronutrient for normal vision and it is present in high concentrations in the eye. It protects the eye by filtering the light and by its antioxidant properties. Lutein is widely available in foods, e.g. in green leafy vegetables, eggs and red peppers.

Samples of the essential oil hydrodistilled from the flowers and leaves of *Tagetes erecta* from Hungary were characterized by limonene, α-terpinolene, piperitone and caryophyllene; the main components of samples from India were: limonene 7%, (Z)-β-ocimene 42%, dihydrotagetone 14%, cis-tagetone 8%, cis-ocimenone 5% and trans-ocimenone 6%. The essential oil appears to be a strong fungicide. At an average concentration of 2000 ppm it is more active than many commercial fungicides such as captan and agrosan (potassium chlorate). Thiophenes and thiophene derivatives with nematicidal properties are present in the leaves and roots of *Tagetes erecta* and other *Tagetes* species. Much research is done to study the positive effects of intercropping commercial field crops with *Tagetes erecta*, particularly in India.

Adulterations and substitutes Lutein is also present in common feedstuffs such as maize and other cereals, capsicum fruits and alfalfa. However, to achieve desired egg yolk pigmentation cereal diets other than maize require additional lutein since their lutein content is highly variable. Astaxanthin is a substitute commercially derived from the yeast *Paffia rhodozyma*. Synthetic colorants or pigments used in poultry feed are citraxanthin, canthaxanthin, β-apo-8'-carotenoic acid and some of its derivatives. Though egg yolk pigmentation due to synthetic colorants is much more intense than with natural ones, an increase in consumer preference for natural organic products ensures a continued demand for natural sources of lutein.

Tagetes essential oil is also (and mostly) extracted from *Tagetes minuta* L. (including the closely related or possibly identical *Tagetes glandulifera* Schrank).

Description Erect annual herb up to 180 cm tall, glabrous; stem and branches angular to rounded. Leaves opposite in lower part of plant, alternate in upper part, pinnately compound with 9–17 leaflets; leaflets linear to lanceolate, 1–3 cm × 0.5–1.5 cm, acute or acuminate at both ends, margins serrate, bearing scattered oil glands. Inflorescence a solitary terminal head, (2–)5–12 cm in diameter; peduncle 3–12 cm long, apex more or less swollen, hollow; involucre campanulate with 4–10 acute or obtuse lobes each bearing 2 rows of linear glands. Ray flowers female, ligulate, 5–8 in wild types, in cultivars often very numerous, ligule broadly obovate, 1–2.5 cm × 1–2 cm, bright yellow in wild types, lemon-yellow to deep brown-red in cultivated types; disk flowers bisexual, tubular, numerous, 8–10 mm long; stamens 5, anthers united into a tube around the style; ovary inferior, 1-celled, style 2-branched. Fruit an angular achene 7–10 mm long, black, glabrous or finely hispid, with pappus of basally connate scales, 1–2 scales up to 1 cm long, the rest much shorter and up to 0.5 cm long.



Tagetes erecta – 1, flowering branch; 2, flower head in longitudinal section.
Redrawn and adapted by Achmad Satiri Nurhaman

Other botanical information *Tagetes* comprises about 40 species which are all indigenous to tropical America, usually occurring in mountainous regions.

Although *Tagetes patula* L. has been considered synonymous to *Tagetes erecta* in several flora accounts for tropical America, it is often distinguished as a separate species, especially when taking into account cultivated plants. However, there are no reliable characteristics to distinguish *Tagetes erecta* and *Tagetes patula*, though the former is reportedly diploid and the latter tetraploid. In cultivation numerous intermediate specimens occur.

Growth and development Once established, *Tagetes erecta* can grow up to more than 1 m tall, although in the wild it usually reaches only 25 cm. Flowering starts about 3 months after planting and continues for several months.

Ecology The natural habitat of *Tagetes erecta* is the pine-oak forest zone of Mexico in a warm, low-humidity climate. In addition to being cultivated as a garden ornamental, it is often found as an escape, e.g. in the United States, where it occurs along roadsides. It needs full sun and in the tropics it occurs from sea-level up to 2000 m altitude. It grows well in well-drained loamy and clay soils of varying pH.

Propagation and planting Propagation of *Tagetes erecta* is by seed. Under good conditions about 400 g/ha is required. Germination is within two weeks and usually seedlings are first transplanted into pots before being planted in single or double rows in the field at about 20 cm × 90 cm. *Tagetes erecta* is sometimes intercropped or grown in rotation with commercial crops to reduce diseases and nematode populations.

Management For commercial growth of *Tagetes erecta*, a fertile soil and preferably 6 hours of sun per day are needed. Weeding is necessary until the crop canopy has closed. Though it needs to be watered regularly, too much watering may cause the plant to rot. Excessive nitrogen or shade leads to the production of leafy plants with few flower heads. Phosphorus promotes flowering.

Diseases and pests A number of diseases and pests can attack *Tagetes erecta*. Botrytis blight causes the flower heads to turn brown and decay, especially in wet weather; a grey mould develops on the fading flowers. A leaf spot causes oval to irregular grey to black spots on the leaflets, starting on lower leaves and progressing upwards. Although *Tagetes erecta* can reduce the numbers of some nematodes in the soil (especially *Pratylenchus penetrans*), root-knot nematodes may cause serious damage. Red spider mite is often a serious pest in *Tagetes erecta* cultivars, causing leaves to lose their green colour; severe infestations cover the plant with fine webbing. Slugs are a major cause of damage too.

Harvesting Plants are considered mature and ready for harvesting when they have 2–3 fully developed flower heads, about 90 days after planting. The flower heads can be harvested by hand or mechanically. Harvesting by hand is done at intervals of 3–5 weeks, depending on plant vigour, until flowering finishes.

Yield In Peru 1000–1200 kg of marigold meal can be obtained per ha. Good lutein yields are 20–25 kg/ha.

Handling after harvest Harvested flower heads are dried directly or after silage up to about 10% moisture content. They can then be ground, packed and sold as marigold or tagetes meal. The ground flower heads can also be extracted with a solvent, hexane being preferred. After removal of the solvent a brown oleoresin is obtained, which can be incorporated directly into poultry feed. The resin can be further purified by saponification with 40% potassium hydroxide or an equivalent alkali solution. After removal of the solvent and adjustment of the pH to 6–8, the product can be washed and sold as saponified marigold extract. It can be further purified by washing and taken up in a suitable vegetable oil or absorbed on e.g. calcium silicate, gelatin and starch to produce a dry powder suitable for use as a food colorant. The final product usually contains 10–20% by weight of the original lutein esters. An alternative extraction method has been developed that eliminates the wasteful silage process. It involves adding enzymes (e.g. 'Viscozyme') that dissolve the cell walls of ground fresh flower heads. Further addition of proteolytic (e.g. 'Neutrase') or pectolytic (e.g. 'Pectinex') enzymes increases the yield of the subsequent hexane extraction to over 95%.

Genetic resources As a commonly grown plant, *Tagetes erecta* is widespread and not in danger of genetic erosion. Small collections of germplasm are maintained, e.g. at the Mendel Agricultural and Forestry University, Lednice, Czech Republic.

Breeding Numerous cultivars have been made in *Tagetes erecta*, almost all for their ornamental value, differing in flower colour, flowerhead size and plant height. Breeding programmes to obtain cultivars with a higher lutein content in the flowers exist in India.

Prospects *Tagetes erecta* is exploited for use as a colorant source in poultry farming and human food. Its cultivation for export for these purposes takes place currently mainly in Mexico and Peru. The expansion of its cultivation to African countries (existing already on a small scale in Zambia and South Africa) might bring an additional source of income to peasant farmers. *Tagetes erecta* can be grown in variable environments and its adoption as a commercial crop seems quite possible in many regions of Africa. World demand depends on developments in its approval as a food colorant and on quality/price competitiveness with other natural lutein sources.

Major references Bosma, Dole & Maness, 2003; Francis, 1999; Gilman & Howe, 1999; Green, 1995; Hind, Jeffrey & Scott, 1993; Santos-Bocanegra, Ospina-Osorio & Oviedo-Rondón, 2004; Schweppe, 1993; Singh et al., 2003; Williams, 1976.

Other references Abid & Maqbool, 1990; Alam, Khan & Saxena, 1998; Arora, 1989; Baghel & Gupta, 1986; Barzana et al., 2002; Gurib-Fakim, Guého & Bissoondoyal, 1995; Hétherlyi et al., 1992; Ijani & Mmbaga, 1988; Ketel, 1987; Kokwaro, 1993; Medhane et al., 1985; Medina & BeMiller, 1993; Perwez, Rahman & Haider, 1988; Prasad & Haque, 1982; Raponda-Walker & Sillans, 1961; Ravindran, 1995; Rodríguez & Mabry, 1977; Steiner, 1941; Strother, 1977; Williams, 1992.

Sources of illustration Hind, Jeffrey & Scott, 1993.

Authors M.P. Setshogo

TERMINALIA CHEBULA Retz.

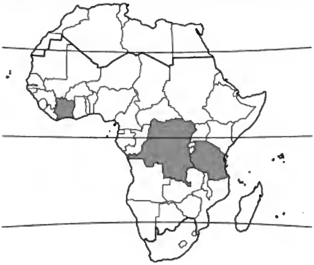
Protologue Observ. bot. 5: 31 (1788).

Family Combretaceae

Chromosome number $2n = 24, 36, 48, 72$

Vernacular names Chebulic myrobalan, chebulic myrabolan, black myrobalan (En). Cadou, myrobalan noir, myrobolan noir, myrobolan chébulique (Fr). Mirabolano quebúlico (Po).

Origin and geographic distribution *Terminalia chebula* occurs naturally from the sub-Himalayan region of Nepal and northern India to Sri Lanka, Myanmar, Thailand, Indo-China and southern China. It has been introduced in tropical Africa where individual trees are occasionally cultivated (e.g. in Côte d'Ivoire, DR Congo and Tanzania).



Terminalia chebula – planted

Uses The fruits of *Terminalia chebula* are rich in tannin and are used on a large scale in India in the leather industry, usually combined with syntans and other vegetable tanning materials such as black wattle (*Acacia mearnsii* De Wild.), avaram (*Senna auriculata* (L.) Roxb.) and yellow mangrove (*Ceriops tagal* (Perr.) C.B.Rob.). *Terminalia chebula* is used in the production of sole leather, and in a last tannage after chrome tanning to give the leather weight and a fast colour. An extract of the fruits is suitable for pretannage of cattle hides. The fruits are also used in calico dyeing and printing, both as auxiliaries and as dyes; their tannins act as mordants to fix the dyes onto the cotton cloth and the unctuous consistence of the pulp makes the surface of the cloth suitably smooth to receive fine printed or painted designs. A reaction of the tannins with iron salts produces black dyes and inks. Brownish yellow to brown dyes for cotton and wool are prepared from the fruits with an alum mordant. The flowers give a yellow dye used for painting yellow and green details on calicos (chintzes). The tanning material (myrobalan) is also used as a mordant for basic aniline dyes and in the silk spinning industry to give some weight back to degummed silk.

The fruits are considered laxative, stomachic, tonic and alterative, and are often used in combination with emblic myrobalan (*Phyllanthus emblica* L.) and beleric myrobalan (*Terminalia bellirica* (Gaertn.) Roxb.). In Ayurvedic medicine the fruits of these 3 species are collectively called 'triphala' and are used to treat headache, dyspepsia, liver complaints, ascites, leucorrhoea and as a purgative, blood purifier and to improve mental faculties. They are also credited with anti-inflammatory, analgesic, anti-arthritic, hypoglycaemic and anti-aging properties.

Fruits of chebulic myrobalan are highly nutritious and could be an important dietary supplement for vitamin C, energy, protein and mineral nutrients. The wood is used as construction timber and for furniture, carts and implements, but is not of much value.

Production and international trade India is by far the main producing country of chebulic myrobalan. The production of dried fruits in

1981 was estimated at more than 100,000 t. Only a fraction (about 20%) of this was exported, as dried fruits, complete or crushed, or as extract, not only to countries in the region, but also to Europe and the United States. In trade, fruits are usually known by place of origin; those from Salem (Karnataka, India) are considered the best. Trees are usually only felled when no longer important for fruit production. No data are available on the amounts of timber produced.

Properties The dried fruit pulp has an average tannin content of about 30%, but the content varies considerably with the place of origin. Poor samples may register less than 20% tannin, good ones over 40%. Solid extracts as well as spray-dried myrobalan extracts are prepared, containing about 60% tannin. Other parts of the plant such as roots, bark, wood and leaves also contain tannin, but less than the fruits. The tannin of the fruits is classified as an ellagitannin and is quite complex in nature. The major constituents are chebulagic acid, chebulinic acid and corilagin. A number of hydrolysis products are present in variable proportions, such as chebulic acid, ellagic acid and gallic acid. Myrobalans contain more sugar-like components than most other tanning materials, about 3–5%, which causes ready fermentation and satisfactory plumping of the hide in the early stages of tanning. They produce a brownish deposit on the leather, called bloom. The tannin is of a 'mild' type and penetrates hides slowly. Used alone, myrobalans produce a soft, spongy, pale yellow leather of poor wearing quality. They are usually mixed with tannins of the proanthocyanidin group, such as extracts of wattle and mangrove bark or quebracho wood, to give the leather more weight.

The mixture of tannin compounds, sugar and other fruit pulp substances make myrobalans a particularly useful product to mordant and prepare the surface of cotton cloth in the Turkish red dyeing process and in calico printing.

The medicinal properties of *Terminalia chebula* have been tested in numerous experiments in Asian countries. Extracts showed antioxidant activity. Fruit extracts exhibited significant inhibitory activity on oxidative stress and the age-dependent shortening of the telomeric DNA length, and thus an inhibitory effect on cellular aging. They also have shown cardioprotective effect against experimentally induced myocardial injury in rats. A crude extract of the fruits inhibited cancer cell growth in several malignant cell lines, with chebulinic acid, tannic acid and ellagic acid as the most inhibitory phenolics. Antidiabetic effects of the extract have also been demonstrated.

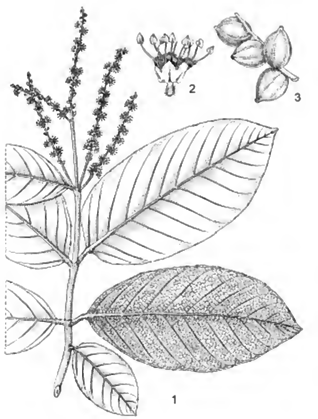
The fruits showed antiviral activities. Gallic acid and 3 galloyl glucoses were isolated as inhibitors of human immunodeficiency virus type 1 (HIV-1) integrase. Extracts inhibited replication of human cytomegalovirus (CMV), and may be beneficial for the prophylaxis of CMV disease in immuno-compromised patients. They also showed activity against herpes simplex virus type 1 (HSV-1). Antibacterial activities have been demonstrated. An extract inhibited glycolysis of salivary bacteria and may serve as an anticaries agent. Topical administration of a leaf extract accelerated the healing process of wounds in rats, partly by possessing antimicrobial activity.

Per 100 g, fresh fruits contain approximately: water 58 g, energy 600 kJ (143 kcal), protein 4 g, carbohydrate 9 g, Ca 128 mg, Mg 67 mg, P 64 mg.

The heartwood is greyish brown to reddish brown and distinctly demarcated from the yellowish grey to grey sapwood. The density is about 880 kg/m^3 at 12% moisture content. The wood is strong and tough, with interlocked grain and fine texture, durable under cover but not in contact with the ground. It is very difficult to season and work.

Description Deciduous tree up to 30 m tall, with a usually short cylindrical bole up to 10 m long and up to 80(–130) cm in diameter; bark dark brown, usually longitudinally cracked with woody scales; crown rounded, with spreading branches. Leaves alternate or opposite, simple and entire; stipules absent; petiole 1–3 cm long, provided with 2 glands near apex; blade ovate to elliptical-obovate, 7–15 cm × 4–10 cm, cuneate to slightly cordate at base, obtuse to acute at apex, thinly leathery, pubescent beneath, pinnately veined. Inflorescence an axillary or terminal, simple or branched spike 3–7 cm long. Flowers bisexual or male, regular, 5-merous, small, yellowish white, unpleasantly scented; calyx with glabrous tube; corolla absent; stamens 10, exserted; ovary inferior, 1-celled, style simple. Fruit an obovoid or cylindrical-ellipsoid drupe 2.5–5 cm long, faintly 5-angular, yellow to orange-brown when ripe, glabrous, 1-seeded. Seedling with epigeal germination, with a long, fairly thin primary root, short and thick hypocotyl, and glabrous cotyledons with 3 prominent and 2 less conspicuous veins.

Other botanical information *Terminalia*



Terminalia chebula – 1, flowering branch; 2, flower; 3, fruits.
Source: PROSEA

is a pantropical genus of about 200 species. In tropical Africa about 30 species occur naturally, but *Terminalia chebula* is introduced and only occasionally planted.

Growth and development The germinative power of *Terminalia chebula* seeds is poor. Viability of the seed is retained for about 1 year. Seedling growth is comparatively slow, with 10–20 cm height attained by the end of the first season and 25–50 cm by the end of the second season. Growth rates are slow in later stages too. The flowers appear together with the new leaves after the tree has been leafless for several months. Fruits ripen some 8 months later, and fall soon after ripening.

Ecology Under natural conditions in Asia *Terminalia chebula* occurs in mixed deciduous forest, extending into forests of comparatively dry types. It ascends to considerable elevations, up to 1500 m or even 2000 m altitude and grows on a variety of soils, clayey as well as sandy. It is a light-demander, but withstands some shade in youth, and may then benefit from protection from the sun. It is fairly tolerant of frost and drought, and withstands fire, recovering well from burning and also from coppicing. Regeneration of natural stands from seed is usually poor, maybe because people harvest the fruit, but also because of predation by animals.

Propagation and planting The fallen fruits are collected and dried thoroughly first. Later the hardened flesh is removed. Fermentation of the stones gives the best germinative results, but clipping the broad end of the stone without damaging the embryo, followed by soaking in cold water for 36 hours gives good results too. Direct sowing is not advisable, because of the risk of predation and because the seeds germinate poorly. In India, seeds are usually sown in boxes or nursery beds before the rainy season, covered with soil, and watered regularly. A mere 20% success is reported. Transplanting from the nursery into the field can be done in the first or second rainy season. Shading is desirable in early stages in the nursery and after transplanting. Propagation by cuttings is possible, but less successful than transplanting nursery-raised seedlings. In the forest, regeneration is facilitated by creating small gaps in the canopy, and this may be supplemented by sowing seeds in the clearings.

Management The tree coppices well. The resulting shoots are 2–3 m long after 5 years.

Diseases and pests *Terminalia chebula* does not suffer from any serious disease or pest, although some defoliators have been reported. Fallen fruits are heavily predated by rodents and insects. The timber is attacked by borers.

Harvesting Fruits are collected from the time they begin to turn yellow until they are quite yellow and ripe.

Yield Per year one *Terminalia chebula* tree yields up to 10 kg fruit.

Handling after harvest The fruits are sun dried, avoiding wetting by rain. They shrivel considerably during drying. Myrobalans are transported as whole fruits, or crushed without the stones, or as extracts. For the extraction of tannin and the preparation of extracts the crushed fruits are infused for 8–10 hours with hot water in a series of vats. The tan-liquor is left to settle in a tank at a temperature of 60°C. To prevent fermentation, bleaching agents such as sodium hydrosulphite, alum or oxalic acid are often added; sometimes sodium acetate or formate are also added. The tan-liquor is concentrated in evaporators. The concentrated solution is fed into vacuum pans for preparing solid extracts, or through an atomizer for preparing spray-dried extracts. Various methods of reducing sludge formation in the tan-liquor and of utilizing the tannin more efficiently have been suggested. They include solvent-extraction of the fruits with chloroform or acetone, heating the extract at about 120°C, ultraviolet irradiation of the powdery extract, passing chlorine through the tan-liquor, and reducing the acidity of the liquor by treating it with salts and acetate buffers. Controlling of the pH of the tan-liquor seems to be the most promising method.

For making myrobalan mordant for calico printing and the Turkish red dye process, crushed fruit flesh is first soaked in water for one night. For treating approximately 5 kg of cotton, 2 kg of dry fruits are necessary. The liquid is filtered and the cotton plunged into it and then dried without washing. To dry the cloth, it is spread out evenly in the sun. Without a mordant, dyeing with myrobalans gives a brownish yellow colour to textile fibres, but by mordanting or printing with Fe compounds a black dye develops on the cloth. Myrobalans also serve as mordants, together with alum, for other dyes, such as the red dye from Indian madder (*Rubia cordifolia* L.). To dye wool yellowish brown, about 1 kg of fruits for 2 kg of wool is boiled in water. The seeds are removed, water is added and the wool is plunged into the dye bath, which is kept boiling for one hour. For a deep brown colour, the same process is followed, with 2 kg of myrobalans added to an already used Indian madder dye-bath.

Whenever possible, the timber should be sawn when the wood is still green. Slow seasoning in protected and close-stacked piles is best to avoid cracking and splitting.

Genetic resources *Terminalia chebula* is widespread and does not seem to be in danger of genetic erosion.

Prospects *Terminalia chebula* might be an interesting source of tanning material for Africa. Because it is the fruit that yields the tannin, harvesting is not injurious to the trees, in contrast to trees of which the bark is harvested as tanning material. The nutritive and numerous medicinal properties of the fruits make chebulic myrobalan an interesting multipurpose tree worth planting on a larger scale.

Major references Burkill, 1985; Cardon, 2003; CSIR, 1976; Fundter, de Graaf & Hildebrand, 1991; Mohanty, Chandramouli & Naik, 1987.

Other references Ahn et al., 2002; Barthakur & Arnold, 1991; Jagtap & Karkera, 1999; Kurokawa et al., 1995; Na et al., 2004; Naik et al., 2003; Sabu & Kuttan, 2002; Saleem et al., 2002; Sosef et al., 1995; Suguna et al., 2002; Yukawa et al., 1996.

Sources of illustration Fundter, de Graaf & Hildebrand, 1991.

Authors P.C.M. Jansen

Based on PROSEA 3: Dye and tannin-producing plants.

TERMINALIA SCUTIFERA Planch. ex M.A.Lawson

Protologue Oliv., Fl. trop. Afr. 2: 417 (1871).

Family Combretaceae

Origin and geographic distribution *Terminalia scutifera* is a strictly West African coastal species distributed from Guinea Bissau to Sierra Leone.

Uses The bark of *Terminalia scutifera* yields a yellow dye, which is used in Sierra Leone to colour clothes and fibres of plant origin. In Sierra Leone the wood is used to make knee-pieces and curved parts of the hulls of fishing boats. A bark extract is used to wash sore feet.

Botany Deciduous small tree up to 15 m tall, with gnarled bole, low branching; bark of branchlets finely longitudinally furrowed, pale brown. Leaves alternate, often crowded at the ends of branchlets, simple and entire; stipules absent; petiole up to 2 cm long; blade oblanceolate to narrowly obovate, 8–19 cm × 3–8 cm, base acute, apex acuminate, thinly leathery, densely red-brown tomentose when young, later glabrescent. Inflorescence a spike up to 8 cm long; peduncle c. 3 cm long. Flowers bisexual, regular, 5-merous, white; receptacle tubular, with 5 acute calyx lobes reflexed in open flowers; petals absent; stamens 10; ovary inferior, densely red-brown tomentose, 1-celled, style simple. Fruit a sessile, glabrous, rhomboid drupe c. 2.5 cm × 3.5 cm, with 2 narrow wings, dark brown.

Terminalia is pantropical and comprises about 200 species. In tropical mainland Africa about 32 indigenous species occur, in Madagascar 37. Several species are cultivated pantropically, e.g. *Terminalia catappa* L. The fruits of *Terminalia scutifera* have often been confused with those of *Terminalia superba* Engl. & Diels and its leaves with those of *Terminalia ivorensis* A.Chev. The bark of the latter two species also yields yellow to reddish brown dyes and black dyes if mordanted with iron-rich mud or iron salts. They are used, for instance in Côte d'Ivoire, to dye wraps, matting and basket fibres, but these species are primarily used as timber.

Ecology *Terminalia scutifera* is confined to coastal habitats with mangrove swamp vegetation or freshwater swamp forest just above the high tide line.

Genetic resources and breeding *Terminalia scutifera* is rather common and not in danger of genetic erosion as long as the mangrove vegetations in its comparatively small distribution area are not endangered.

Prospects *Terminalia scutifera* will remain a minor local source for dyeing.

Major references Burkill, 1985; Griffiths, 1957.

Other references Keay, 1954a; Lawson, 1871; Miège, 1992; Raponda-Walker & Sillans, 1961.

Authors P.C.M. Jansen

XYLOCARPUS GRANATUM J.König

Protologue Naturforscher 20: 2 (1784).

Family Meliaceae

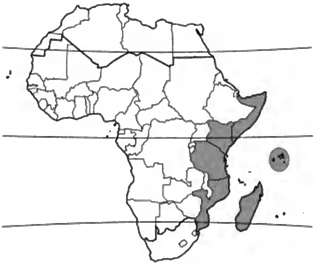
Chromosome number $2n = 42, 52, 58$

Synonyms *Carapa obovata* Blume (1825), *Xylocarpus obovatus* (Blume) A.Juss. (1830), *Carapa granatum* (J.König) Alston (1931).

Vernacular names Cannonball mangrove (En). Mangalbola de canhão (Po). Mkomafi, mtifi (Sw).

Origin and geographic distribution *Xylocarpus granatum* is widely distributed in coastal regions of the Old World tropics, from East Africa and Madagascar through tropical Asia, to tropical Australia and Polynesia.

Uses The bark of the bole of *Xylocarpus granatum* is rich in tannin and is used for tanning heavy hides into sole leather and other heavy leather, and for toughening and preserving fishing nets. It is sometimes used to dye cloth brownish or reddish. The wood is a good mahogany-like timber, but as the trunk is usually crooked and hollow, long straight pieces cannot be cut. It is used in boat building, and for nails, house-posts, wood carvings, tool handles and furniture, but it is not resistant to termites. In India the wood is found suitable for second grade pencils. It can also be used as firewood, but it burns quickly and produces great heat, which is why other sources are preferred. The oil extracted from seeds has been used as an illuminant and as hair oil. The astringent bark has some medicinal uses. It is used to treat dysentery, diarrhoea and other abdominal troubles, and as a febrifuge. The fruit is used in India to treat swellings of the breast and elephantiasis. Burned seeds have been used mixed with sulphur and coconut oil against itchy skin. On Mafia Island (Tanzania) a decoction of the crushed fruits is drunk as an aphrodisiac.

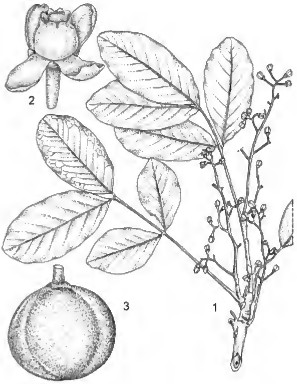


Xylocarpus granatum – *wild*

Production and international trade The bark is used only locally for tanning and dyeing purposes because natural supply is not abundant. *Xylocarpus granatum* is usually not found in pure stands and its bark is thin. The wood is of local importance only.

Properties Most parts of the plant contain tannin: bark, wood, leaves and fruits. However, the bark of mature trees is richest in tannin, containing 20–34% on dry matter base. The tannin penetrates hides rapidly and produces a reddish brown, tough leather, but nothing is known about its composition. The seeds yield 1–2% of oil. The wood is reported to contain 0.1% gedunin, a limonoid, with antimalarial activity that is found in many other *Meliaceae* species, e.g. neem (*Azadirachta indica* A.Juss.). In Malaysia an aqueous seed extract showed significant in-vitro antifilarial activity against *Brugia malayi*. The wood is moderately heavy with a density of 630–790 kg/m^2 at 15% moisture content, and moderately hard and durable. The heartwood is reddish, darkening to a deep warm brown on exposure, usually sharply demarcated from the narrow, buff-coloured to silver-grey sapwood. The grain is straight or slightly interlocked, texture fine and even. The wood shrinks little and is usually easy to work and finish, and it takes a high polish. The pulping and paper making properties of *Xylocarpus granatum* are rated as poor.

Description Small to medium-sized tree up to 15(–20) m tall; bole often of poor form, up to 90 cm in diameter, with thin, branched ribbon-like surface roots; bark thin, smooth, scaly with irregular flakes, whitish to yellow-brown, inner bark reddish pink. Leaves alternate, paripinnately compound, with 1–2(–3) pairs of leaflets; stipules absent; petiole and rachis up to 12 cm long; petiolules 2–11 mm long, thickened; leaflets elliptical or obovate, 4–12 cm × 2–6 cm, base cuneate, apex rounded, entire, leathery. Inflorescence an axillary thyrse up to 6 cm long, often forked with indistinct main axis. Flowers functionally unisexual, regular, 4-merous; pedicel 3–9 mm long, thickened near the calyx; calyx lobed to about the middle, lobes 1–3 mm long; petals free, oblong, 3.5–6.5 mm × 2–3 mm, creamy-white or pinkish; stamens 8, united into a tube 2–3.5 mm in diameter; disk well developed, 8-lobed, red; ovary superior, 4-celled, style short and thick, stigma large. Fruit a globose, pendulous, woody capsule 12–25 cm in diameter, weighing up to 3 kg, tardily dehiscing by 4 valves from apex, 6–20-seeded. Seeds irregularly tetrahedral, up to 6 cm long, brown, with a corky seedcoat. Seedling with hypogeal germination, initially with scale leaves, first leaves simple.



Xylocarpus granatum – 1, flowering branch; 2, female flower; 3, fruit.
Source: PROSEA

Other botanical information *Xylocarpus* is a small genus, comprising 3 species which are very similar, and consequently have often been confused. In tropical Africa and the African Indian Ocean islands only 2 species are found: *Xylocarpus granatum* and *Xylocarpus rumphii* (Kostel.) Mabb. In most African floras *Xylocarpus rumphii* is erroneously named *Xylocarpus moluccensis* (Lam.) M.Roem., which in fact is the third species and restricted to tropical Asia and Australia and not in Africa. *Xylocarpus rumphii* is not a mangrove species, growing on sandy and rocky coasts and has no ribbon-like surface roots. It has ovate, slightly acuminate leaflets and fruits of 6–8 cm in diameter. Its bark is rough and longitudinally fissured, and can also be used for tanning purposes, although in Africa the species is less common than *Xylocarpus granatum*. The wood of *Xylocarpus rumphii* is occasionally used, e.g. for masts and furniture in Kenya.

Anatomy Wood-anatomical description:

- Macroscopic characters:
  Heartwood reddish, darkening to a deep warm brown on exposure, usually sharply demarcated from the narrow, buff-coloured to silver-grey sapwood. Grain straight or slightly interlocked. Texture fine and even. Wood with darker streaks producing attractive watered-silk figure on tangential surfaces. Growth rings distinct or indistinct.

Growth and development Trees are usually evergreen, even in seasonal climates, but are sometimes deciduous. They sucker basally when they are damaged, and depauperate plants may develop several trunks. Growth is according to Rauh's architectural model, characterized by a monopodial trunk which grows rhythmically and develops tiers of branches. Each new flush is marked by a few scales followed by pinnate leaves. Flowering is usually in the rainy season. Flowers are functionally unisexual, male flowers having a non-functional, rather slender ovary, female flowers having non-functional stamens either never dehiscent or with sterile pollen. It has been observed that certain individuals, although flowering profusely, never produce fruit; this suggests that dioecism sometimes occurs. Flowers are probably pollinated by short-tongued insects like bees. Usually only one fruit develops per inflorescence. The corky testa of the seed represents an adaption to dispersal by water, and seeds may start to germinate while still floating. Germinated seeds do not become readily established in the mud but are often washed away with the tide. This may contribute to the prominence of the species at higher elevations in a mangrove.

Ecology *Xylocarpus granatum* is a mangrove plant, found in tidal mud of mangrove swamps, especially towards their upper limits. It tolerates a salinity of 0.1–3%.

Propagation and planting In natural conditions, the seeds of *Xylocarpus granatum* float just below the water surface and are dispersed by ocean currents. Seed viability decreases rapidly upon storage. Seeds should be sown with the convex side upwards. They show about 70% germination in 1–2.5 months. Seedlings can attain 50 cm height in 3 months. Direct sowing has been successfully applied in a trial plantation of *Xylocarpus granatum* at 1 m × 1 m. *Xylocarpus* is a moderate light demander, particularly enduring shade when young. A decrease in freshwater supply during the dry season can result in high mortality.

Management In mangrove forests, *Rhizophora* and *Bruguiera* species are usually considered more valuable than *Xylocarpus* which is sometimes cut down to promote growth of the other species. Large *Xylocarpus granatum* trees are often crooked and gnarled, and the bole is hollow, which makes it difficult to obtain large timber sizes.

Harvesting The bark is peeled from the tree for use in local tanneries. The tree recovers easily from the peeling.

Handling after harvest Usually the bark is directly used in the tannery or for toughening nets.

Genetic resources *Xylocarpus* species are comparatively common and widespread and do not seem endangered, except that mangrove forest have been cut in many regions. In locations where *Xylocarpus* is cut in favour of other mangrove species, it can become endangered.

Prospects The cultivation of *Xylocarpus granatum* in the drier mangrove areas is worth considering. It might be an interesting plant for industrial tannage because the tree recovers easily after the bark has been removed. In addition, it is easy to propagate and has a comparatively high tannin content.

Major references Mabberley, Pannell & Sing, 1995; Rudjiman, 1991b; Styles & White, 1991; Sukardjo, 1998; Tomlinson, 1986; White & Styles, 1963.

Other references Allen, Krauss & Hauff, 2003; Barbosa, Cuambe & Bandeira, 2001; Beentje, 1994; CSIR, 1950; Decary, 1946; Hassan & Cheek, 1999; Kokwaro, 1993; Mainoya, Mesaki & Banyikwa, 1986; Shinoda, Iwata & Tayima, 1987; White, Styles & Gonçalves, 1979; Zaridah et al., 2001.

Sources of illustration Rudjiman, 1991b.

Authors P.C.M. Jansen

Based on Prosea 3: Dye and tannin-producing plants.

Dyes and tannins with other primary use

List of species in other commodity groups (parenthesis), which are used also as dye or tannin. Synonyms are given in the indented lines (7 July 2005).
The names listed here have not been repeated in the Index of scientific plant names (p. 206).

- *Abelmoschus moschatus* (essential oils and exudates)
  - *Hibiscus abelmoschus*
- *Abutilon mauritianum* (fibres)
  - *Pavonia patens*
- *Acacia bussei* (fuel plants)
- *Acacia dealbata* (essential oils and exudates)
- *Acacia decurrens* (fuel plants)
- *Acacia etbaica* (fuel plants)
- *Acacia farnesiana* (essential oils and exudates)
- *Acacia lahai* (fuel plants)
- *Acacia melanoxylon* (timbers)
- *Acacia mollissima* (essential oils and exudates)
- *Acacia natalitia* (stimulants)
  - *Acacia karroo*
- *Acacia nigrescens* (timbers)
- *Acacia pennata* (medicinal plants)
  - *Acacia pentagona*
- *Acacia polyacantha* (essential oils and exudates)
  - *Acacia campylacantha*
- *Acacia saligna* (fuel plants)
- *Acacia senegal* (essential oils and exudates)
  - *Mimosa senegal*
  - *Senegalia senegal*
- *Acacia seyal* (essential oils and exudates)
- *Acacia sieberiana* (essential oils and exudates)
- *Acacia tortilis* (forages)
  - *Acacia raddiana*
  - *Acacia spirocarpa*
- *Adansonia digitata* (vegetables)
- *Adenanthera pavonina* (timbers)
- *Adenostemma viscosum* (medicinal plants)
- *Aegle marmelos* (fruits)
- *Afzelia africana* (timbers)
- *Albizia anthelmintica* (medicinal plants)
- *Albizia chevalieri* (fibres)
- *Albizia coriaria* (timbers)
- *Albizia gummifera* (timbers)
  - *Albizia fastigiata*
- *Albizia lebbeck* (auxiliary plants)
- *Albizia schimperiana* (timbers)
- *Alchornea cordifolia* (medicinal plants)
- *Allanblackia stuhlmannii* (vegetable oils)
- *Allanblackia ulugurensis* (vegetable oils)
- *Aloe lateritia* (medicinal plants)
  - *Aloe graminicola*
- *Aloe nyerensis* (medicinal plants)
- *Aloe tweediae* (medicinal plants)
- *Amaranthus cruentus* (vegetables)
  - *Amaranthus hybridus* ssp. *cruentus* var. *paniculatus*
  - *Amaranthus paniculatus*
- *Anacardium occidentale* (fruits)
- *Annona reticulata* (fruits)
- *Annona senegalensis* (fruits)
  - *Annona arenaria*
  - *Annona chrysophylla*
- *Annona squamosa* (fruits)
- *Anthonotha macrophylla* (timbers)
  - *Macrolobium macrophyllum*
- *Anthonotha obanensis* (timbers)
  - *Isomacrolobium obanense*
- *Antiaris toxicaria* (timbers)
- *Antrocaryon klaineanum* (timbers)
- *Aphloia theiformis* (fruits)
- *Ardisia humilis* (medicinal plants)
  - *Ardisia solanacea*
- *Artocarpus heterophyllus* (fruits)
- *Averrhoa bilimbi* (fruits)
- *Averrhoa carambola* (fruits)
- *Avicennia germinans* (timbers)
  - *Avicennia africana*
  - *Avicennia nitida*
- *Avicennia marina* (timbers)
  - *Avicennia officinalis*
- *Azadirachta indica* (auxiliary plants)
- *Balanites aegyptiaca* (fruits)
- *Baphia laurifolia* (timbers)
- *Barringtonia asiatica* (timbers)
- *Basella alba* (vegetables)
  - *Basella cordifolia*
  - *Basella lucida*
  - *Basella rubra*
- *Bauhinia kalantha* (medicinal plants)
- *Bauhinia petersiana* (cereals and pulses)
- *Bauhinia purpurea* (ornamentals)
- *Bauhinia rufescens* (ornamentals)
- *Bauhinia tomentosa* (ornamentals)
- *Bauhinia variegata* (ornamentals)
- *Berchemia discolor* (fruits)
  - *Phyllogeiton discolor*

- *Beta vulgaris* (vegetables)
- *Bidens pilosa* (vegetables)
  - *Bidens leucantha*
- *Blighia sapida* (fruits)
- *Bobgunnia madagascariensis* (timbers)
  - *Swartzia madagascariensis*
- *Bombax brevicuspe* (fibres)
  - *Rhodognaphalon brevicuspe*
- *Bombax buonopozense* (fibres)
- *Bombax costatum* (fruits)
- *Bombax rhodognaphalon* (timbers)
  - *Bombax stolzii*
- *Borassus aethiopum* (fruits)
- *Boswellia microphylla* (essential oils and exudates)
- *Boswellia neglecta* (medicinal plants)
  - *Boswellia hildebrandtii*
- *Boswellia sacra* (essential oils and exudates)
  - *Boswellia carteri* var. *undulato-crenata*
- *Brachystegia boehmii* (ornamentals)
  - *Brachystegia woodiana*
- *Brachystegia spiciformis* (timbers)
- *Brackenridgea zanguebarica* (medicinal plants)
- *Bridelia ferruginea* (fuel plants)
- *Bridelia micrantha* (timbers)
  - *Bridelia stenocarpa*
- *Bridelia scleroneura* (fuel plants)
  - *Bridelia scleroneuroides*
- *Burasaia madagascariensis* (fruits)
- *Burkea africana* (timbers)
- *Butea monosperma* (ornamentals)
  - *Butea frondosa*
- *Caesalpinia decapetala* (ornamentals)
  - *Caesalpinia sepiaria*
- *Caesalpinia pulcherrima* (ornamentals)
- *Caesalpinia volkensii* (medicinal plants)
- *Calendula officinalis* (ornamentals)
- *Calophyllum laxiflorum* (fruits)
- *Calotropis procera* (medicinal plants)
- *Camellia sinensis* (stimulants)
- *Campylospermum glaberrimum* (ornamentals)
  - *Ouratea glaberrima*
- *Canna* ×*generalis* (carbohydrates)
  - *Canna bidentata*
  - *Canna edulis*
  - *Canna indica*
- *Capsicum annuum* (vegetables)
  - *Capsicum chinense*
  - *Capsicum frutescens*
- *Caralluma speciosa* (medicinal plants)
- *Carissa macrocarpa* (fruits)
- *Carthamus tinctorius* (vegetable oils)
- *Cassia abbreviata* (medicinal plants)
- *Cassia fistula* (ornamentals)
- *Cassia javanica* (ornamentals)
  - *Cassia agnes*
  - *Cassia nodosa*
- *Cassia sieberiana* (medicinal plants)
- *Cassine transvaalensis* (timbers)
- *Cassytha filiformis* (medicinal plants)
- *Casuarina equisetifolia* (fuel plants)
- *Cathormion altissimum* (medicinal plants)
  - *Albizia altissima*
  - *Pithecellobium altissimum*
- *Ceiba pentandra* (fibres)
  - *Eriodendron anfractuosum*
- *Cephalosphaera usambarensis* (timbers)
- *Ceratonia siliqua* (timbers)
- *Chamaecrista absus* (medicinal plants)
  - *Cassia absus* L.
- *Chlorophytum suffruticosum* (medicinal plants)
  - *Anthericum suffruticosum*
- *Chloroxylon swietenia* (timbers)
- *Chrozophora plicata* (medicinal plants)
- *Chrozophora senegalensis* (medicinal plants)
- *Chrysobalanus icaco* (fruits)
  - *Chrysobalanus ellipticus*
  - *Chrysobalanus orbicularis*
- *Cissus aralioides* (medicinal plants)
- *Citrullus colocynthis* (medicinal plants)
  - *Colocynthis vulgaris*
- *Citrullus lanatus* (vegetables)
  - *Citrullus vulgaris*
  - *Colocynthis citrullus*
  - *Momordica lanata*
- *Citrus aurantifolia* (fruits)
- *Clerodendrum splendens* (ornamentals)
- *Clerodendrum umbellatum* (ornamentals)
  - *Clerodendrum cordifolium*
  - *Clerodendrum scandens*
- *Clitoria ternatea* (ornamentals)
- *Cnestis ferruginea* (medicinal plants)
- *Cocculus hirsutus* (medicinal plants)
- *Cochlospermum planchonii* (fibres)
- *Cochlospermum vitifolium* (ornamentals)
- *Cocos nucifera* (vegetable oils)
- *Cola acuminata* (stimulants)
- *Cola cordifolia* (ornamentals)
- *Cola nitida* (stimulants)
- *Cola rostrata* (timbers)
- *Combretum adenogonium* (medicinal plants)
  - *Combretum fragrans*
  - *Combretum ghasalense*
  - *Combretum ternifolium*
- *Combretum erythrophyllum* (timbers)
- *Combretum hartmannianum* (medicinal plants)
- *Combretum micranthum* (medicinal plants)
- *Combretum molle* (medicinal plants)
  - *Combretum microlepidotum*
  - *Combretum sokodense*
- *Combretum mucronatum* (medicinal plants)

- *Combretum smeathmannii* (continued)
- *Combretum nigricans* (essential oils and exudates)
- *Combretum paniculatum* (medicinal plants)
- *Commelina benghalensis* (vegetables)
  - *Commelina pyrrhoblepharis*
- *Commiphora africana* (essential oils and exudates)
- *Conocarpus erectus* (fuel plants)
- *Conyza attenuata* (medicinal plants)
  - *Conyza persicariifolia*
- *Cordeauxia edulis* (cereals and pulses)
- *Cordia myxa* (medicinal plants)
- *Crateva adansonii* (fruits)
  - *Crateva religiosa*
- *Crinum jagus* (medicinal plants)
  - *Crinum giganteum*
- *Crossopterix febrifuga* (timbers)
- *Crotalaria agatiflora* (medicinal plants)
- *Crotalaria incana* (auxiliary plants)
- *Crotalaria pallida* (auxiliary plants)
  - *Crotalaria falcata*
  - *Crotalaria mucronata*
  - *Crotalaria striata*
- *Crotalaria retusa* (auxiliary plants)
- *Croton megalocarpus* (timbers)
- *Curtisia dentata* (timbers)
- *Cussonia arborea* (timbers)
  - *Cussonia barteri*
  - *Cussonia djalonensis*
  - *Cussonia kirkii*
- *Cyanastrum cordifolium* (ornamentals)
- *Cyathula uncinulata* (medicinal plants)
  - *Cyathula sphaerocephala*
- *Cycnium tubulosum* (medicinal plants)
  - *Rhamphicarpa heuglinii*
  - *Rhamphicarpa montana*
  - *Rhamphicarpa tubulosa*
- *Cyperus latifolius* (fibres)
- *Cyperus madagascariensis* (fibres)
- *Cyperus papyrus* (fibres)
- *Cyphomandra betacea* (fruits)
- *Dalbergia sissoo* (timbers)
- *Dalbergia tricolor* (fuel plants)
- *Danais fragrans* (essential oils and exudates)
- *Daniellia oliveri* (essential oils and exudates)
- *Datura fastuosa* (medicinal plants)
  - *Datura alba*
  - *Datura metel*
- *Datura stramonium* (medicinal plants)
- *Daucus carota* (vegetables)
- *Delonix elata* (ornamentals)
- *Delonix regia* (ornamentals)
- *Desmodium ramosissimum* (medicinal plants)
- *Desplatsia chrysochlamys* (fruits)
- *Desplatsia dewevrei* (fruits)
- *Desplatsia subericarpa* (fibres)
- *Detarium microcarpum* (medicinal plants)
- *Dictyandra arborescens* (timbers)
- *Dillenia indica* (timbers)
- *Diospyros canaliculata* (medicinal plants)
- *Diospyros cooperi* (timbers)
- *Diospyros dendo* (timbers)
  - *Diospyros atropurpurea*
  - *Diospyros flavescens*
- *Diospyros lycioides* (fibres)
- *Diospyros mespiliformis* (fruits)
- *Diospyros soubreana* (medicinal plants)
- *Distemonanthus benthamianus* (timbers)
- *Dodonaea viscosa* (medicinal plants)
  - *Dodonaea angustifolia*
- *Dovyalis caffra* (auxiliary plants)
- *Dracaena mannii* (ornamentals)
  - *Dracaena perrottetii*
  - *Dracaena usambarensis*
- *Echinochloa stagnina* (cereals and pulses)
- *Eclipta prostrata* (medicinal plants)
  - *Eclipta alba*
- *Ekebergia capensis* (timbers)
  - *Ekebergia ruepelliana*
  - *Ekebergia senegalensis*
- *Elaeis guineensis* (vegetable oils)
- *Elaeodendron matabelicum* (timbers)
  - *Cassine matabelica*
- *Elephantorrhiza goetzei* (fibres)
- *Elephantorrhiza suffruticosa* (medicinal plants)
- *Enantia chlorantha* (timbers)
- *Enantia kummeriae* (medicinal plants)
  - *Annickia kummeriae*
- *Enantia polycarpa* (timbers)
- *Englerina woodfordioides* (medicinal plants)
  - *Loranthus woodfordioides*
- *Ensete ventricosum* (carbohydrates)
  - *Ensete edule*
  - *Musa ensete*
  - *Musa ventricosa*
- *Entada africana* (medicinal plants)
  - *Entada sudanica*
- *Entada chrysostachys* (timbers)
- *Entada gigas* (fibres)
  - *Entada scandens*
- *Entandrophragma angolense* (timbers)
- *Ervatamia coronaria* (ornamentals)
- *Erythrina abyssinica* (timbers)
  - *Erythrina tomentosa*
- *Erythrina mildbraedii* (ornamentals)
  - *Erythrina klainei*
- *Erythrophleum ivorense* (medicinal plants)
- *Erythrophleum suaveolens* (medicinal plants)
  - *Erythrophleum guineense*
- *Eucalyptus camaldulensis* (fuel plants)
  - *Eucalyptus rostrata*

- *Eucalyptus robusta* (timbers)
- *Euclea crispa* (medicinal plants)
- *Euclea natalensis* (medicinal plants)
  - *Euclea fructuosa*
- *Euclea racemosa* (fruits)
  - *Euclea schimperi*
- *Eugenia coronata* (ornamentals)
- *Eugenia uniflora* (fruits)
- *Euphorbia hirta* (medicinal plants)
  - *Chamaesyce hirta*
- *Eurypetalum batesii* (timbers)
- *Faidherbia albida* (auxiliary plants)
  - *Acacia albida*
- *Faurea rochetiana* (timbers)
  - *Faurea speciosa*
- *Faurea saligna* (timbers)
- *Ficus asperifolia* (medicinal plants)
  - *Ficus acutifolia*
  - *Ficus pendula*
  - *Ficus urceolaris*
  - *Ficus warburgii*
- *Ficus capreifolia* (fibres)
- *Ficus cordata* (ornamentals)
  - *Ficus lecardii*
- *Ficus lutea* (ornamentals)
  - *Ficus baronii*
  - *Ficus trichosphaera*
  - *Ficus vogelii*
- *Ficus mucuso* (ornamentals)
- *Ficus platyphylla* (essential oils and exudates)
- *Ficus sansibarica* (fruits)
  - *Ficus macrosperma*
- *Ficus sur* (timbers)
  - *Ficus capensis*
  - *Ficus mallotocarpa*
  - *Ficus riparia*
- *Ficus sycomorus* (fruits)
  - *Ficus cocculifolia*
  - *Ficus gnaphalocarpa*
  - *Ficus sakalavarum*
- *Ficus umbellata* (ornamentals)
- *Ficus vogeliana* (timbers)
- *Flemingia macrophylla* (auxiliary plants)
- *Flueggea virosa* (medicinal plants)
  - *Securinega virosa*
- *Fuerstia africana* (medicinal plants)
- *Galium spurium* (medicinal plants)
- *Garcinia buchananii* (timbers)
- *Garcinia kola* (stimulants)
- *Garcinia livingstonei* (fruits)
- *Garcinia mangostana* (fruits)
- *Gardenia erubescens* (timbers)
- *Gardenia ternifolia* (timbers)
  - *Gardenia jovis-tonantis*
  - *Gardenia lutea*
  - *Gardenia triacantha*
- *Gardenia vogelii* (ornamentals)
- *Gmelina arborea* (timbers)
- *Gomphrena globosa* (ornamentals)
- *Gongronema latifolium* (medicinal plants)
  - *Marsdenia latifolia*
- *Gossypium arboreum* (fibres)
- *Gossypium barbadense* (fibres)
- *Grewia mollis* (timbers)
  - *Grewia pubescens*
- *Griffonia simplicifolia* (fibres)
  - *Bandeiraea simplicifolia*
- *Guibourtia coleosperma* (timbers)
- *Guiera senegalensis* (medicinal plants)
- *Hagenia abyssinica* (medicinal plants)
  - *Brayera anthelmintica*
  - *Hagenia anthelmintica*
- *Haldina cordifolia* (timbers)
  - *Adina cordifolia*
- *Harpephyllum caffrum* (fruits)
- *Harungana madagascariensis* (timbers)
  - *Haronga madagascariensis*
- *Heliotropium ramosissimum* (medicinal plants)
  - *Heliotropium undulatum*
- *Heritiera littoralis* (timbers)
  - *Heritiera minor*
- *Heritiera utilis* (timbers)
  - *Tarrietia utilis*
- *Hibiscus rosa-sinensis* (ornamentals)
- *Hibiscus sabdariffa* (vegetables)
- *Hydnora africana* (fruits)
- *Hymenocardia acida* (medicinal plants)
- *Hymenocardia ulmoides* (timbers)
- *Hypericum revolutum* (medicinal plants)
- *Hyphaene coriacea* (carbohydrates)
  - *Hyphaene hildebrandtii*
  - *Hyphaene natalensis*
  - *Hyphaene shatan*
- *Hyphaene thebaica* (timbers)
- *Hypoestes forskaolii* (medicinal plants)
- *Hypoestes triflora* (medicinal plants)
- *Impatiens balsamina* (ornamentals)
- *Indigofera argentea* (forages)
- *Indigofera conjugata* (medicinal plants)
- *Indigofera diphylla* (forages)
- *Indigofera hirsuta* (medicinal plants)
- *Indigofera oblongifolia* (forages)
- *Indigofera parviflora* (forages)
- *Indigofera spicata* (auxiliary plants)
  - *Indigofera hendecaphylla*
- *Indigofera vohemarensis* (essential oils and exudates)
- *Intsia bijuga* (timbers)
  - *Afzelia bijuga*
- *Ipomoea asarifolia* (medicinal plants)
  - *Ipomoea repens*
- *Ipomoea batatas* (carbohydrates)

Jacaranda mimosifolia (ornamentals)
Jamesbrittenia atropurpurea (medicinal plants)
  Sutera atropurpurea
Jasminum dichotomum (ornamentals)
Jasminum fluminense (ornamentals)
  Jasminum mauritianum
Jasminum sambac (ornamentals)
Jatropha curcas (medicinal plants)
Juniperus procera (timbers)
Keetia leucantha (medicinal plants)
Khaya ivorensis (timbers)
Khaya nyasica (timbers)
Khaya senegalensis (timbers)
Kigelia africana (medicinal plants)
  Kigelia aethiopica
  Kigelia pinnata
Kiggelaria africana (timbers)
Lablab purpureus (cereals and pulses, vegetables)
  Dolichos lablab
  Lablab niger
  Lablab vulgaris
Labramia bojeri (vegetable oils)
Lagerstroemia speciosa (ornamentals)
Lannea acida (medicinal plants)
Lannea amaniensis (medicinal plants)
Lannea discolor (fruits)
Lannea schweinfurthii (fruits)
  Lannea stuhlmannii
Lannea welwitschii (timbers)
Lantana camara (medicinal plants)
Lantana trifolia (medicinal plants)
Laportea oligoloba (essential oils and exudates)
  Urera oligoloba
Leonotis nepetifolia (medicinal plants)
  Leonotis africana
Leonotis ocymifolia (medicinal plants)
  Leonotis raineriana
Leptolaena bojerianum (medicinal plants)
Leucaena leucocephala (auxiliary plants)
  Leucaena glauca
Leucas martinicensis (medicinal plants)
Lonchocarpus sericeus (ornamentals)
Ludwigia abyssinica (vegetables)
  Jussiaea abyssinica
Lumnitzera racemosa (fuel plants)
Maclura africana (medicinal plants)
  Cardiogyne africana
Maerua crassifolia (timbers)
Maerua triphylla (medicinal plants)
Maesa lanceolata (medicinal plants)
Maesa nuda (medicinal plants)
Mallotus subulatus (medicinal plants)
Mangifera indica (fruits)
  Fegimanra africana
Manilkara mochisia (fruits)
Manilkara obovata (timbers)
  Chrysophyllum obovatum
  Manilkara angolensis
  Manilkara lacera
  Manilkara multinervis
Maranthes goetzeniana (timbers)
Maranthes polyandra (fuel plants)
  Parinari polyandra
Markhamia tomentosa (ornamentals)
Maytenus senegalensis (timbers)
  Gymnosporia senegalensis
Medicago sativa (forages)
Mesembryanthemum crystallinum (medicinal plants)
Mimosa pigra (medicinal plants)
Mimosa pudica (medicinal plants)
Mimusops coriacea (fruits)
Mimusops elengi (timbers)
Mirabilis jalapa (ornamentals)
Mitragyne inermis (timbers)
Morinda citrifolia (medicinal plants)
Morinda geminata (timbers)
Morinda longiflora (medicinal plants)
Morinda morindoides (medicinal plants)
Moringa oleifera (vegetables)
  Moringa pterygosperma
Mucuna pruriens (auxiliary plants)
  Mucuna aterrima
  Mucuna cochinchiniensis
  Mucuna nivea
Mundulea sericea (medicinal plants)
Musa (fruits)
Musanga cecropioides (timbers)
Mystroxylon aethiopicum (fruits)
  Cassine aethiopica
  Elaeodendron oliganthum
Nicotiana tabacum (stimulants)
Nyctanthes arbor-tristis (medicinal plants)
Nymphaea nouchali (carbohydrates)
  Nymphaea caerulea
  Nymphaea calliantha
  Nymphaea capensis
Ochna arborea (timbers)
Ochna schweinfurthiana (ornamentals)
Oldenlandia corymbosa (medicinal plants)
  Oldenlandia caespitosa
Oldenlandia herbacea (medicinal plants)
Opuntia tuna (auxiliary plants)
Oryza sativa (cereals and pulses)
Osyris quadripartita (timbers)
  Osyris abyssinica
  Osyris lanceolata
Oxyanthus subpunctatus (ornamentals)
Paederia bojeriana (medicinal plants)
Paraserianthes falcataria (auxiliary plants)

  - *Albizia falcataria*
  - *Albizia moluccana*
  - *Falcataria moluccana*
- *Parinari curatellifolia* (fruits)
  - *Parinari mobola*
- *Parinari excelsa* (timbers)
  - *Parinari holstii*
- *Parkia biglobosa* (spices and condiments)
  - *Mimosa biglobosa*
  - *Parkia africana*
  - *Parkia clappertoniana*
- *Parkia filicoidea* (timbers)
- *Pauridiantha callicarpoides* (timbers)
- *Pauridiantha hirtella* (timbers)
  - *Urophyllum hirtellum*
- *Peganum harmala* (stimulants)
- *Peltophorum pterocarpum* (ornamentals)
- *Pemphis acidula* (timbers)
- *Pennisetum glaucum* (cereals and pulses)
  - *Pennisetum americanum*
  - *Pennisetum spicatum*
  - *Pennisetum typhoides*
- *Pentaclethra macrophylla* (timbers)
- *Pergularia tomentosa* (medicinal plants)
- *Pericopsis laxiflora* (timbers)
  - *Afrormosia laxiflora*
- *Persea americana* (fruits)
  - *Persea gratissima*
- *Persicaria senegalensis* (vegetables)
  - *Polygonum senegalense*
- *Phagmanthera usuiensis* (medicinal plants)
- *Phoenix dactylifera* (fruits)
- *Phoenix reclinata* (fibres)
- *Phyllanthus fraternus* (medicinal plants)
- *Phyllanthus muellerianus* (medicinal plants)
  - *Phyllanthus floribundus*
- *Phyllanthus reticulatus* (medicinal plants)
- *Physalis peruviana* (fruits)
- *Physostigma venenosum* (medicinal plants)
- *Phytolacca dioica* (auxiliary plants)
- *Phytolacca dodecandra* (medicinal plants)
- *Piliostigma malabaricum* (forages)
- *Piliostigma reticulatum* (fibres)
  - *Bauhinia reticulata*
- *Piliostigma thonningii* (fibres)
  - *Bauhinia thonningii*
- *Pithecellobium dulce* (auxiliary plants)
- *Plectranthus comosus* (carbohydrates)
- *Plumbago auriculata* (medicinal plants)
  - *Plumbago capensis*
- *Plumbago zeylanica* (medicinal plants)
- *Poga oleosa* (timbers)
- *Pongamia pinnata* (timbers)
- *Premna hispida* (medicinal plants)
- *Prosopis africana* (timbers)
- *Prosopis glandulosa* (auxiliary plants)
- *Prunus persica* (fruits)
  - *Amygdalus persica*
  - *Persica vulgaris*
- *Pseudocedrela kotschyi* (timbers)
- *Pseudolachnostylis maprouneifolia* (medicinal plants)
- *Psidium guajava* (fruits)
  - *Psidium pomiferum*
- *Psorospermum febrifugum* (medicinal plants)
- *Pterocarpus erinaceus* (timbers)
- *Pterocarpus lucens* (timbers)
  - *Pterocarpus abyssinicus*
- *Pterocarpus osun* (timbers)
- *Pterocarpus santalinoides* (timbers)
- *Punica granatum* (fruits)
- *Pycnocoma macrophylla* (medicinal plants)
- *Rauvolfia vomitoria* (medicinal plants)
- *Rhamnus prinoides* (spices and condiments)
- *Rhizophora harrisonii* (fuel plants)
- *Rhizophora mangle* (fuel plants)
- *Rhizophora mucronata* (timbers)
- *Rhizophora racemosa* (fuel plants)
- *Rhoicissus tridentata* (medicinal plants)
  - *Rhoicissus erythrodes*
- *Rhus crenulata* (fruits)
- *Rhus glaucescens* (fruits)
- *Rhus glutinosa* (timbers)
  - *Rhus abyssinica*
- *Rhus lancea* (fruits)
- *Rhus lucida* (timbers)
- *Rhus tenuinervis* (fruits)
- *Rhus tripartita* (fruits)
- *Rhus undulata* (fruits)
  - *Rhus burchellii*
- *Rhus viminalis* (timbers)
- *Ricinus communis* (vegetable oils)
- *Rothmanniia engleriana* (fruits)
- *Rothmanniia fischeri* (timbers)
- *Rothmanniia manganjae* (fruits)
  - *Gardenia manganjae*
- *Rothmanniia munsae* (medicinal plants)
  - *Randia lane-poolei*
  - *Randia megalostigma*
- *Rothmannia urcelliformis* (medicinal plants)
  - *Randia stenophylla*
- *Rourea orientalis* (medicinal plants)
  - *Byrsocarpus orientalis*
  - *Dalbergia tingens*
- *Rumex abyssinicus* (vegetables)
  - *Rumex schimperi*
- *Rumex nepalensis* (vegetables)
  - *Rumex bequaertii*
  - *Rumex quarrei*
  - *Rumex steudelii*
- *Saba comorensis* (fruits)
  - *Landolphia florida*

  - *Saba florida*
- *Sageretia thea* (forages)
- *Salix subserrata* (fuel plants)
- *Sarcocephalus latifolius* (fruits)
  - *Nauclea latifolia*
  - *Sarcocephalus esculentus*
- *Schinus molle* (ornamentals)
- *Schleichera trijuga* (fuel plants)
  - *Schleichera oleosa*
- *Schotia brachypetala* (timbers)
- *Schrebera arborea* (timbers)
- *Sclerocarya birrea* (fruits)
  - *Poupartia birrea*
  - *Poupartia caffra*
  - *Sclerocarya caffra*
- *Sclerocroton integerrimus* (medicinal plants)
  - *Sapium integerrimum*
- *Securidaca longipedunculata* (medicinal plants)
- *Senna alata* (medicinal plants)
  - *Cassia alata*
- *Senna didymobotrya* (medicinal plants)
  - *Cassia didymobotrya*
- *Senna obtusifolia* (vegetables)
  - *Cassia obtusifolia*
- *Senna occidentalis* (stimulants)
  - *Cassia occidentalis*
- *Senna podocarpa* (medicinal plants)
  - *Cassia podocarpa*
- *Senna siamea* (fuel plants)
  - *Cassia siamea*
- *Senna singueana* (medicinal plants)
  - *Cassia goratensis*
  - *Cassia singueana*
- *Senna spectabilis* (ornamentals)
  - *Cassia spectabilis*
- *Senna surattensis* (ornamentals)
  - *Cassia surattensis*
- *Senna tora* (stimulants)
  - *Cassia tora*
- *Sesbania grandiflora* (ornamentals)
- *Sida rhombifolia* (fibres)
- *Sida schimperiana* (medicinal plants)
- *Solanecio mannii* (auxiliary plants)
  - *Crassocephalum mannii*
  - *Crassocephalum multicorymbosum*
  - *Senecio mannii*
- *Solanum nigrum* (medicinal plants)
- *Solanum scabrum* (vegetables)
  - *Solanum guineense*
- *Solenostemma argel* (medicinal plants)
  - *Solenostemma oleifolium*
- *Sonneratia alba* (timbers)
- *Sorghum arundinaceum* (forages)
  - *Sorghum aethiopicum*
  - *Sorghum verticilliflorum*
  - *Sorghum virgatum*
- *Sorindeia warneckei* (fruits)
- *Sphenostylis marginata* (carbohydrates)
  - *Sphenostylis erecta*
- *Spondias mombin* (fruits)
- *Staudtia kamerunensis* (timbers)
  - *Staudtia gabonensis*
  - *Staudtia stipitata*
- *Sterculia appendiculata* (timbers)
- *Stereospermum kunthianum* (medicinal plants)
- *Striga asiatica* (medicinal plants)
- *Striga aspera* (medicinal plants)
- *Striga hermonthica* (medicinal plants)
- *Strombosia grandifolia* (timbers)
- *Stylochaeton lancifolius* (carbohydrates)
- *Swietenia macrophylla* (timbers)
- *Swietenia mahagoni* (timbers)
- *Symphonia globulifera* (timbers)
  - *Symphonia gabonensis*
- *Syzygium aromaticum* (spices and condiments)
  - *Caryophyllus aromaticus*
  - *Eugenia aromatica*
  - *Eugenia caryophyllus*
- *Syzygium cordatum* (timbers)
- *Syzygium cumini* (fruits)
  - *Eugenia jambolana*
- *Syzygium emirnense* (fruits)
  - *Eugenia cuneifolia*
- *Syzygium guineense* (timbers)
  - *Memecylon lopezianum*
- *Syzygium jambos* (fruits)
  - *Eugenia jambos*
- *Syzygium owariense* (fruits)
- *Tagetes minuta* (essential oils and exudates)
- *Tagetes patula* (ornamentals)
- *Talinum triangulare* (vegetables)
- *Tamarindus indica* (fruits)
- *Tamarix articulata* (auxiliary plants)
- *Tarchonanthus camphoratus* (timbers)
- *Tectona grandis* (timbers)
- *Tephrosia purpurea* (auxiliary plants)
- *Tephrosia vogelii* (medicinal plants)
- *Terminalia arjuna* (medicinal plants)
- *Terminalia avicennioides* (medicinal plants)
- *Terminalia bellirica* (medicinal plants)
- *Terminalia brownii* (timbers)
- *Terminalia catappa* (ornamentals)
- *Terminalia ivorensis* (timbers)
- *Terminalia laxiflora* (medicinal plants)
- *Terminalia macroptera* (timbers)
- *Terminalia mantaly* (ornamentals)
- *Terminalia mollis* (fuel plants)
- *Terminalia schimperiana* (medicinal plants)
  - *Terminalia glaucescens*
- *Terminalia sericea* (timbers)
- *Terminalia superba* (timbers)

Theobroma cacao (stimulants)
Thespesia danis (timbers)
Thespesia populnea (timbers)
Thunbergia alata (ornamentals)
Tithonia diversifolia (auxiliary plants)
Toona ciliata (timbers)
Trema orientalis (auxiliary plants)
  Trema guineensis
Trichilia djalonis (timbers)
Trichilia emetica (vegetable oils)
  Trichilia roka
Trichilia monadelpha (timbers)
  Limonia monadelpha
  Trichilia heudelotii
  Trichilia velutina
Trichodesma ambacense (medicinal plants)
  Trichodesma hockii
Trichoscypha longifolia (timbers)
Trigonella foenum-graecum (spices and condiments)
Trilepisium madagascariense (fruits)
  Bosqueia angolensis
  Bosqueia boiviniana
  Bosqueia phoberos
Triumfetta cordifolia (fibres)
Triumfetta rhomboidea (fibres)
Tylosema fassoglensis (cereals and pulses)
  Bauhinia fassoglensis
Uapaca acuminata (timbers)
Uapaca heudelotii (timbers)
Uapaca sansibarica (fruits)
Uvaria chamae (medicinal plants)
Uvaria kirkii (fruits)
Vernicia cordata (vegetable oils)
  Aleurites cordata
Vernicia fordii (vegetable oils)
  Aleurites fordii
Vernicia montana (vegetable oils)
  Aleurites montana
Vernonia auriculifera (fibres)
Vismia rubescens (essential oils and exudates)
Vitellaria paradoxa (vegetable oils)
  Butyrospermum niloticum
  Butyrospermum paradoxum
  Butyrospermum parkii
Vitex doniana (timbers)
  Vitex cienkowskii
  Vitex cuneata
Weinmannia bojeriana (medicinal plants)
Weinmannia eriocarpa (medicinal plants)
Whitfieldia elongata (medicinal plants)
  Whitfieldia longifolia
Woodfordia fruticosa (medicinal plants)
  Woodfordia floribunda
Woodfordia uniflora (fuel plants)
Xeroderris stuhlmannii (timbers)
  Ostryoderris stuhlmannii
Ximenia americana (fruits)
Zanthoxylum usambarense (timbers)
Zea mays (cereals and pulses)
Zingiber officinale (spices and condiments)
Ziziphus abyssinica (fruits)
Ziziphus mauritiana (fruits)
  Ziziphus jujuba
Ziziphus mucronata (fruits)

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PROTA
Plant Resources of Tropical Africa
Ressources végétales de l'Afrique tropicale

PROTA in short

The Plant Resources of Tropical Africa (PROTA) programme was initiated in 2000 and developed into an international partnership of 11 institutions in 11 countries during the Preparatory Phase 2000–2003. Since 19 February 2003, PROTA operates as an international foundation domiciled in Wageningen, Netherlands.

PROTA is a major 'information brokerage and knowledge repatriation' programme. The objectives are to bring the 'world literature' on the useful plants of Tropical Africa, now accessible only to the resourceful happy few, into the (African) public domain, and contribute to greater awareness and sustained use of the plants, with due respect for traditional knowledge and intellectual property rights. PROTA will describe the estimated 7,000 useful plants during the Implementation Phase 2003-2012. The information carriers will be freely accessible Web databases (www.prota.org), a low-price Handbook and CD-Rom series featuring 16 Commodity groups, and Special Products per commodity group for rural development, education, research and policy actors (all in English and French).

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PROTA 2: Vegetables (2004)
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PROTA, P.O.Box 341, 6700 AH Wageningen, Netherlands (www.prota.org) partageons les connaissances au profit des communautés rurales

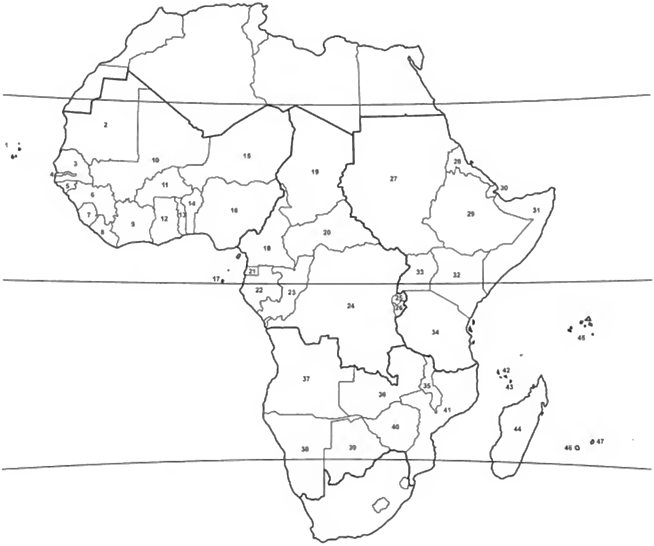
sharing knowledge, improving rural livelihoods

CTA in short

The Technical Centre for Agricultural and Rural Cooperation (CTA) was established in 1983 under the Lomé Convention between the ACP (African, Caribbean and Pacific) Group of States and the European Union Member States. Since 2000, it has operated within the framework of the ACP-EC Cotonou Agreement.

CTA's tasks are to develop and provide services that improve access to information for agricultural and rural development, and to strengthen the capacity of ACP countries to produce, acquire, exchange and utilise information in this area. CTA's programmes are designed to: provide a wide range of information products and services and enhance awareness of relevant information sources; promote the integrated use of appropriate communication channels and intensify contacts and information exchange (particularly intra-ACP); and develop ACP capacity to generate and manage agricultural information and to formulate ICM strategies, including those relevant to science and technology. CTA's work incorporates new developments in methodologies and cross-cutting issues such as gender and social capital.

CTA, P.O.Box 380, 6700 AJ Wageningen, Netherlands (www.cta.int)



WEST AFRICA

1. Cape Verde
2. Mauritania
3. Senegal
4. Gambia
5. Guinea Bissau
6. Guinea
7. Sierra Leone
8. Liberia
9. Côte d'Ivoire
10. Mali
11. Burkina Faso
12. Ghana
13. Togo
14. Benin
15. Niger
16. Nigeria

CENTRAL AFRICA

17. São Tomé et Principe
18. Cameroon
19. Chad
20. Central African Republic
21. Equatorial Guinea
22. Gabon
23. Congo
24. Democratic Republic of Congo
25. Rwanda
26. Burundi

EAST AFRICA

27. Sudan
28. Eritrea
29. Ethiopia
30. Djibouti
31. Somalia
32. Kenya
33. Uganda
34. Tanzania

SOUTHERN AFRICA

35. Malawi
36. Zambia
37. Angola
38. Namibia
39. Botswana
40. Zimbabwe
41. Mozambique

INDIAN OCEAN ISLANDS

42. Comoros
43. Mayotte (Fr)
44. Madagascar
45. Seychelles
46. Réunion (Fr)
47. Mauritius

PROTA, short for 'Plant Resources of Tropical Africa', is an international programme focused on the 7,000 useful plants of Tropical Africa. Its purpose is to make available the wealth of dispersed knowledge on these plant resources for education, extension, research and industry through Internet databases, books, CD-Roms, and derived products such as brochures, leaflets, and manuals. A thorough knowledge of the plant resources is essential for arriving at ecologically balanced and sustainable land-use systems. A large international team of experts is contributing the texts on particular species. All species are described according to a standard format with details on uses, trade, properties, botany, ecology, agronomy or sylviculture, genetic resources, breeding, prospects and literature. In the printed series the species are grouped into commodity groups. More information on www.prota.org. 'Protabase' can be searched at: database.prota.org/search.htm.

Dyes and tannins

PROTA 3 deals with the dyes and tannins of Tropical Africa. PROTA's database 'SPECIESLIST' presents 659 species used as such, but only 116 are 'primary use' dyes and tannins qualifying for treatment in this volume, the other 543 species have been listed as 'Dyes and tannins with other primary use' and referred to other Handbook volumes.

The 116 'primary use' dyes and tannins are described in 73 review articles by 24 authors, 15 of whom from Africa, implying that 43 species have no separate article due to lack of information; they are only mentioned in the articles of related species.

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